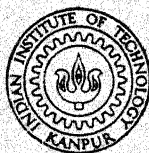


DETERMINATION OF OPTIMAL ROUTES AND VEHICLE DISPATCHING STRATEGIES FOR A DISTRIBUTION NETWORK

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DEPARTMENT OF MECHANICAL ENGINEERING

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DETERMINATION OF OPTIMAL ROUTES AND VEHICLE DISPATCHING STRATEGIES FOR A DISTRIBUTION NETWORK

A Thesis Submitted
In Partial Fulfilment of the Requirements
for the Degree of
MASTER OF TECHNOLOGY

By
JAGJIWAN LAL MODI

to the

**DEPARTMENT OF MECHANICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY KANPUR
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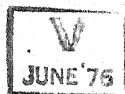
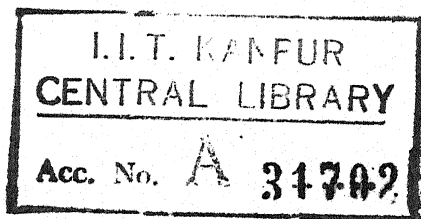
CERTIFICATE

Certified that this work on 'Determination of Optimal Routes and Vehicle Dispatching Strategies for a Distribution Network' by Jagjiwan Lal Modi has been carried out under my supervision and that this has not been submitted elsewhere for a degree.

Kanpur
September 1974

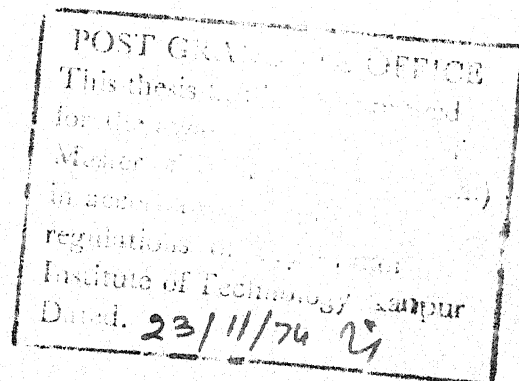
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Kanpur
September 1974

- Jagjiwan Lal Modi

Dedicated to
My Parents and Gudiya

TABLE OF CONTENTS

			<u>Page No.</u>
ACKNOWLEDGEMENT			iv
LIST OF TABLES			vii
LIST OF FIGURES			ix
SYNOPSIS			x
CHAPTER	I	INTRODUCTION	1
CHAPTER	II	LITERATURE SURVEY	4
	2.1	A Critical Survey	4
	2.2	Summary	7
CHAPTER	III	MATHEMATICAL FORMULATION	8
	3.1	Problem Description	8
	3.1.1	Objective Function	8
	3.1.2	Constraints	9
	3.1.3	Basic Assumptions	11
	3.2	Mathematical Formulation	12
	3.2.1	Notations and Terminology	12
	3.2.2	Objective Function	14
	3.2.3	Constraints	15
CHAPTER	IV	METHODOLOGY	19
	4.1	Shortest Distance Model	19
	4.2	Routes Design Model	20
	4.2.1	Determination of Feasible 'sets' of vehicles	21
	4.2.2	Designing the Routes	23
	4.2.3	Construction of Initial Routes	23
	4.2.4	Adjustment of Initial Routes for Satisfying the Constraints	26
	4.2.5	Consideration of Ommitted Customers	31
	4.2.6	Refining Heuristics	31

CHAPTER	V	COMPARISON OF PROPOSED MODEL WITH CLARKE AND WRIGHT'S METHOD	33
CHAPTER	VI	VEHICLE DISPATCHING FOR KANPUR SAHAKARI MILK BOARD - A CASE STUDY	46
	6.1	Operations of Kanpur Sahakari Milk Board	46
	6.2	Data Collection	47
	6.2.1	Aggregation of Delivery Points	48
	6.2.2	Milk as the only Product for Distribution	49
	6.3	Strategies used for the collec- tion of Data	49
CHAPTER	VII	RESULTS AND DISCUSSION	60
	7.1	Results for the Distribution System of Kanpur Sahakari Milk Board	60
	7.2	Comparison of the Total Distribu- tion cost by proposed dispatching policies with that of the currently used policies of Kanpur Sahakari Milk Board	65
	7.3	Effect of Various Vehicle-Set- Selection policies and Vehicle- allocation Policies	65
	7.3.1	Effect of Vehicle-Set-Selection Policies	67
	7.3.2	Effect of Vehicle-allocation Policies	72
	7.4	Sensitive Analysis	77
	7.5	Scope for Further Work	84
BIBLIOGRAPHY			85
APPENDIX		COMPUTER LISTING	89

LIST OF TABLES

<u>Table</u>		<u>Page</u>
5.1	Operating Characteristics of Vehicles and Distribution Costs Involved	35
5.2	Results for Test Problem 1	36
5.3	Results of Test Problem 2	37
5.4	Results for Test Problem 3	38
5.5	Results for Test Problem 4	39
5.6	Results for Test Problem 5	40
5.7	Results for Test Problem 6	41
5.8	Results for Test Problem 7	42
5.9	Results for Test Problem 8	43
5.10	Results for Test Problem 10	44
5.11	Comparison of Results obtained by Proposed Method with Clarke and Wright's Method	45
6.1	Aggregated Zonal Delivery Points	50
6.2(a)	Distance Matrix	52
6.2(b)	Shortest Distance Matrix	53
6.3	Demand Data	55
6.4	Vehicle Capacities	56
6.5	Operating Characteristics of Vehicles and Distribution Costs Involved	57
6.6	Stop-off-time at the Nodes	59
7.1(a)	Results for Summer-morning Demands	61
7.1(b)	Results for Summer-evening Demands	62
7.2(a)	Results for Winter-morning Demands	63
7.2(b)	Results for Winter-evening Demands	64
7.3	Distribution Costs for Existing Distribution System of Kanpur Sahakari Milk Board	66

7.4	Comparison of the Total Distribution Cost by Proposed Dispatching Policies with That of the Currently used Policies of Kanpur Sahakari Milk Board	66
7.5	Total cost of Distribution for Different sets of Demands, using Various Set-Selection-Policies and Vehicle-Allocation Policies	68
7.6	Cost of Maintenance, Depreciation and Labour Cost for Different Sets of Demands, using various Vehicle-Set-Selection Policies	69
7.7	Effect of Variation in Winter-morning Demand set on optimal cost of transportation and total cost of distribution	78
7.8	Recommended Routes and Vehicle-Dispatching Strategies for the Variation of Demands at each customer between -20% and -6% of present Winter-morning demand set	79
7.9	Recommended routes and vehicle-dispatching strategies for the variation of demands at each customer upto +12% of present winter-morning demands	79
7.10	Effect of variation in Summer-morning demand set on optimal cost of transportation and total cost of distribution	81
7.11	Recommended routes and vehicle-dispatching strategies for the variation of demands at each customer upto +10% of present summer-morning demand set.	82

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	Effect of various vehicle-set-selection policies on the maintenance, labour and depreciation cost, for the different sets of demands	70
2	Effect of various vehicle-set-selection policies on the total distribution cost, for the different sets of demands	71
3	Relationship between the demand and total distribution cost, with use of different vehicle-allocation policies and considering vehicle-set-selection policy 1	73
4	Relationship between the demand and total distribution cost, with use of different vehicle-allocation policies and considering vehicle-set-selection policy 2	74
5	Relationship between the demand and the total distribution cost with use of different vehicle-allocation policies and considering vehicle-set-selection policy 3	75
6	Relationship between the demand and the cost transportation with use of various vehicle-allocation policies	76
7	Effect of variation in winter-morning demand on optimal cost of transportation and optimal distribution cost	80
8	Effect of variation in summer-morning demand on optimal cost of transportation and optimal distribution cost	83

SYNOPSIS

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"DETERMINATION OF OPTIMAL ROUTES AND VEHICLE DISPATCHING STRATEGIES FOR DISTRIBUTION NETWORK"

In the present work, an heuristic approach has been developed for designing the optimal routes through customers in a distribution network, for selecting the optimal set of vehicles and for their allocation to the routes designed so as to satisfy customers' demands at the minimum distribution cost. The proposed model can handle the allocation of equal as well as multiple capacity vehicles. This model also takes into account the time constraint - that has not been considered heretofore - for ensuring the distribution of commodity to customers within prescribed time.

Method of solution starts with constructing initial routes by Multiple Travelling Salesman Algorithm. Initial routes are adjusted for the capacity and time constraint, keeping the distribution cost at the minimum possible level. Finally, the refining heuristic are used to improve the routes in order to reduce the distribution cost. A computer package has been developed for the proposed methodology.

Nine test problems have been solved using the proposed methodology. Same set of problems have been solved using Clarke and Wright's method. A comparison of the results

indicate the superiority of the proposed methodology over Clarke & Wright's method in terms of total distribution cost. Further, the proposed model has been tested on a case study based on the distribution system of Kanpur Sahakari Milk Board. It is observed that if the routes and dispatching strategies obtained by the proposed methodology are used, it results in a saving over the currently used policies of Kanpur Sahakari Milk Board. Savings have been observed to vary from 20% to 32% depending upon the time period under consideration.

CHAPTER I

INTRODUCTION

The primary objective of any business organization is to make money. Managers are always on the look out for finding ways and means to reduce the costs of production and distribution so that product reaches the customer at the lowest possible price. If a business is to succeed it must exert no less effort towards the efficient direction and control of distribution costs than towards the production costs. Therefore, most business executives are trying to find ways and means to reduce distribution costs. In many concerns distribution cost constitutes the major cost and in most industries it is a factor of major proportion.

An efficient and economic distribution system is particularly very important for those industries in which the distribution expense represents a major share of the price paid by the ultimate consumer. When there is a buyer's market in any industry, the low-cost distributor has an important edge on competition. Inefficient distribution system leads to reductions in profit and/or dissatisfaction of customers.

Distribution embraces all the activities in an enterprise that are required to move finished goods from the ends of production lines to the points of ultimate sale or use. In an industry which uses vehicles for the distribution of its goods, an attempt for getting an efficient distribution system creates the vehicle-dispatching problem i.e., the problem of designing optimal routes through customers in distribution network, finding an optimal size of fleet and its allocation to the routes

designed, so as to satisfy customers' demands at the minimum delivery cost. Present work attempts to solve such a problem.

Literature on vehicle dispatching problems can be traced back to 1960 when Dantzig & Ramzer (8) attempted the problem as a linear program. Later on, the problem was also formulated in Integer programming terms (1) but large number of variables and constraints precluded the solution of such models. This led to the development of heuristic approaches which could successfully handle real life distribution problems which happened to be large in size. It is to be pointed out that most of the currently available approaches give near optimal solution to the problem. Therefore, better algorithms need to be developed for the efficient generations of optimal solutions. Further, a thorough survey of the literature indicated that most of the research workers have concentrated on models with assumptions of constant capacity vehicles and single product delivery. No extensive work has been reported for the problems incorporating traffic constraints in distribution network and time constraint ensuring the delivery of commodities to customer points in prescribed time. On the other hand, if the model is to be of any practical significance it should also incorporate the cases of multiple capacity vehicles, multi-product distribution, traffic and time constraint etc. The literature review reveals that, but for a brief mention, no serious attempts have been made by the researchers to incorporate the above listed features into their models. In the present work, some of these features have been incorporated. An approach, which is heuristic in character, has been developed for solving vehicle dispatching problems with vehicles having same capacities as well as different capacities and incorporating the constraints for (1) customers' demand satisfaction (2) maximum load on a route depending upon the capacity of vehicle on that route and

(3) route and vehicle time for distribution of commodity to customers within prescribed time. The proposed methodology has been validated using a case study on the distribution system of Kanpur Sahakari Milk Board. Further, the proposed method has been compared with that of Clarke & Wright's method (6) for nine test problems in which the time constraint has been relaxed. The practical application of the proposed model extends to all distribution systems where a fleet of delivery vehicles deliver a commodity from a supplying source to a set of customers with known location.

CHAPTER-II

LITERATURE SURVEY

2.1 A Critical Review:

The problem of producing routes for vehicles servicing a number of customers from a single depot has aroused much interest among the researchers. In general, the objective is to produce a set of routes which minimize the total cost of delivery subject to the restrictions due to the maximum load carrying capacity of the vehicles and the maximum allowable elapsed time (or distance) for any route. The cost factors generally considered are the number of trucks and the total distance travelled to satisfy the customer's demands. The approaches that are cited in literature for solving such problems are discussed in the paragraphs that ensue.

Balinski and Quandt (1) formulated the above problem as an Integer Program. They listed various possible feasible combinations depending upon the number of customers, number of permissible geographical routes and number of customers delivered together by a given vehicle and computed their costs. Problem was then to find a set of activities that satisfy all orders and minimizes total cost. They defined an activity to be a single feasible combination of customers' demands. This model is not useful for large size practical problems because of high number of variables involved.

Dantzig and Ramser (8) proposed a linear programming approach for the truck dispatching problems. The objective was to minimize the interpair distances between delivery points. Their method of solution starts from the basic idea to synthesize the solution in a number of

'Stages of aggregation' in which suboptimizations are carried out on pairs of delivery points or groups. This method tends to lay more emphasis on filling the delivery trucks to near capacity than on minimizing total distance. Therefore, it does not give optimal solution and sometimes results might be far from optimal.

Clarke and Wright (6) developed an heuristic approach to incorporate the practical constraints and formed the basis for most methods developed to date. This approach is called "Savings approach" because in this method the savings for each possible link are calculated and arranged in descending order and then each link is examined in turn by going down the list. If the link under consideration satisfies the constraints of capacity and distance, it is added, otherwise another link is examined, until no more links can be added and we are then left with the final tours. In spite of its simplicity for use, this method does not guarantee optimality for vehicle routes. Nevertheless, the results obtained by this method become progressively worse as the constraints are made more stringent. Gaskell (15) has shown that the results obtained by Clarke & Wrights' method are often far from optimal results. This approach has been successfully used, for some cases, by Norman (28) and by National Computing Centre (29).

Christofides and Eilon (4) generalized the simple methods of solution of the "Travelling Salesman Problem" for solving the truck dispatching problems. They used two techniques namely Branch and Bound technique and "r-optimal tour" technique. Christofides and Eilon observed that the Branch and Bound technique was not practicable for large size vehicle dispatching problems because it required excessive computer time and memory. Further, they found that the computational efficiency of the Branch and Bound algorithm when applied to the vehicle scheduling problems was substantially reduced compared with its efficiency in solving an equivalent Travelling Salesman Problem. Therefore, for large

size problems, they developed 'r-optimal tour' method. They defined 'r-optimal tour' as the tour which cannot be reduced in length by replacing r of its links by r other links. Their method starts with an arbitrary random route structure and each route is examined to see whether mileage can be reduced by re-arranging the customers of that route. The method is then repeated using different initial solutions. In general, the probability that the r -optimal tour is minimal, increases with the value of r . But on other hand, the amount of computations required increases very rapidly with value of r . They claim that 3-optimal tour produced very good results. To substantiate this claim, Christofides and Eilon solved ten problems and compared the results with the results obtained by Clarke and Wrights approach. The results were found to be quite comparable with Clarke & Wright's approach.

The approaches discussed above, are very restrictive in nature because they cannot handle situations when a customer may be served by one of the several depots. Recently, Wren and Holliday (34) presented an algorithm which allows routes from several depots to be constructed simultaneously subject to restrictions on number of vehicles at individual depots and constraints on load and distance. Their approach is first to construct initial feasible routes and then to apply a number of different refining heuristics to the initial routes. The quality of final routes depends very much upon the initial routes constructed. For constructing initial routes, the customers are presented to the algorithm in a predetermined order which affects the quality of initial routes. Refining heuristics further improve the initial routes (improvement being measured in terms of reduction of distance or number of vehicles). Theoretically, the programme might be allowed to continue until none of heuristics could produce an improvement. However, they found that after a spectacular initial leap, the rate of improvement often slowed down considerably. Therefore, they suggested that the program should be terminated after a specified amount of computer time.

2.2 Summary

The review of literature has revealed a number of approaches developed for tackling dispatching problem. The limitations and the relative performances of different models in terms of results obtained and computational efficiencies have also been discussed. However, but for a brief mention, none of these approaches handle the problem of route selection and vehicle dispatching when the delivery vehicles are of different capacities, multiple products are to be delivered to the customers in a pre-specified duration of time.

CHAPTER-III

MATHEMATICAL FORMULATION

3.1 Problem Description

Broadly speaking, the problem can be viewed as designing the optimal delivery routes and the determination of the optimal set of vehicles to be plied on these routes out of the available vehicles of known capacities. Delivery vehicles distribute the commodity from the depot to a set of customers each with a known location and anticipated demand.

Before the mathematical formulation is presented, author feels it in order to discuss briefly the objective function, the various constraints and the assumptions made for the development of the model.

3.1.1 Objective Function

The objective is to minimize total cost of distribution to satisfy a known demand. The various distribution costs are :

- 1) Cost of Transportation: This is the cost of fuel consumed by vehicles in transporting the commodity to customers. Obviously the transportation cost for a delivery vehicle is approximately a linear function of distance travelled by that vehicle.
- 2) Labour Maintenance and Depreciation Costs: Labour cost includes the wages for drivers, helpers and route clerks involved in distribution operations. This cost is a linear function of number of vehicles in operation, because each vehicle is accompanied by driver, route clerk and helpers. Maintenance cost is the cost for maintaining the vehicles for keeping them ready for the operations. It depends upon the condition

of vehicle, frequency of accidents etc. Depreciation cost refers to the fall in value of the vehicle with respect to time.

3.1.2 Constraints:

- 1) Demand Constraint : Routes designed should be such that anticipated demand at each customer point is fully satisfied. In case, the management decides to fix up some quota to be delivered to the customers, demand is considered as to be equal to that quota.
- 2) Capacity Constraint: Vehicle routes should be designed such that the total amount to be delivered by any vehicle, on the route allocated to it, should not be more than its capacity.
- 3) Time Constraint : This constraint is of much importance when commodity to be delivered to customer is perishable one. This constraint is incorporated to restrict the delivery to each customer within permissible time limits.
 - i) Route time constraint: The upper limit for the time elapsed on a route is kept to make sure of deliveries to all customers during the specified time. Route time includes total travelled time on the route and the total stop-off-time at customers' points on that route. This constraint restricts the length of the route and the number of customers to be served on a route.
 - ii) Vehicle time constraint: This constraint comes into picture when a vehicle is assigned to more than one route. In this case, vehicle has to return to depot, after delivering one route, to get loaded for serving next route assigned to it. So loading and unloading of vehicle

at depot is also involved. The total time elapsed from the moment the vehicle is loaded for serving first route assigned to it, to the time this vehicle is unloaded at depot after serving the last route assigned to it, is the vehicle time because for that much time vehicle was in operation continuously. This constraint restricts the number of routes which can be served by the same vehicle. Significance of this constraint is when delivery vehicles are being operated on a shift basis.

At this stage, it is opportune to explain some of the terms used above.

- a) Capacity of Vehicle: Capacity of any vehicle is the maximum permissible load (in terms of weight or volume) which can be carried safely by that vehicle. Capacity of vehicle is also affected by the condition of vehicle.
- b) Stop-off-time at each customer point : Stop-off-time at a customer point includes
 - i) time for unloading the items to be delivered to that customer.
 - ii) time for loading the items returned from that customer.
 - iii) time for preparing bill for money transaction etc.

In General, stop off time at each customer point is different, depending upon the amount of loading and unloading involved.

- c) Stop-off-time at depot: It includes the time for loading and unloading of the vehicle at depot.
- d) Maximum permissible route time: Route time is the elapsed time for which vehicle is on that route, It includes
 - i) travelling time on the route
 - ii) stop off-time for all the customers on the route.

Maximum limit for route time is put for making the deliveries to all customers in a specified time.

- e) Maximum permissible vehicle time: It is the time for which the vehicles are available for the distribution. It includes
 - i) loading and unloading time for the vehicle at depot.
 - ii) vehicle idle time.
 - iii) route time for the route(s) assigned to that vehicle.
- f) Average speed of vehicles Speed of vehicle depends upon its size and condition. In addition to it, average speed of the vehicle depends on the traffic intensity of the route assigned to the vehicle.

3.1.3 Basic Assumptions:

- 1) All delivery vehicles would return to the depot after distributing the commodity to customers. This is usual practice of most of the companies engaged in distribution.
- 2) Only one route passes through a customer and full delivery to that customer is made by the vehicle assigned to that route passing through that customer. This assumption is valid for only those customers whose demand is less or equal to the capacity of vehicle. In fact, most of the distributing agencies follow this strategy.

- 3) All vehicles are in same condition. This assumption implies that maximum allowable load to be carried by vehicles of the same capacity is same.
 - 4) Average permissible speed on the routes is same for a vehicle throughout the distribution network.
 - 5) Supply from source i.e. depot is sufficient to fulfill demands of all the customers.
 - 6) Labour and maintenance cost is same for every vehicle and therefore, the total labour and maintenance cost is considered as a linear function of the number of vehicles.
 - 7) There is no vehicle idle time at the depot due to delay in loading and unloading of vehicle i.e., vehicle is ready for loading or unloading as soon as it reaches the depot. Similary assumption has been made that no vehicle idle time occurs on the route allocated to it.
- Assumptions (3) and (4) follow that average speed of vehicles is no more a function of condition of vehicle or traffic intensity on routes. It is only a function of type of vehicle and its size.

A mathematical formulation of the above stated problem has been presented in the following section.

3.2 Mathematical Formulation

The notations and terminology used for the development of mathematical model is presented below:

3.2.1 Notations and terminology

NC - Number of customers to be served.

N - Total number of nodes in distribution network.

i	Index for the preceeding node $i = 1, 2, \dots, N$
j	Index for the succeeding node, $j = 1, 2, \dots, N$
G	Number of routes
g	Index for the routes, $g = 1, 2, \dots, G$
λ_g	g th route
NV	Number of vehicles employed for the distribution
d_{ij}	Shortest distance between i th & j th node
r	Index for the vehicles, $r = 1, 2, \dots, NV$.
C_r	Capacity of r th vehicle
D_j	Demand at j th node, $j = 2, 3, \dots, N$ $D_1 = 0$ for $j = 1$, i.e., for the depot
y_{ij}	$= 1$ if i th node is connected to j th node in network $= 0$ otherwise
I_{λ_g}	Set of delivery point forming the route λ_g i.e., $j \in I_{\lambda_g}$ such that j is on route λ_g ; for $j \neq 1$.
n_{λ_g}	Number of delivery points forming the route λ_g .
δ_g^r	$= 1$ if r th vehicle is assigned to route λ_g $= 0$ otherwise
t_{sj}	Stop off time at j th customer $j = 2, 3, \dots, N$
L_r	Loading and unloading time for r th vehicle at depot.
K_r	Cost of transportation/unit distance for r th vehicle
T_1	Maximum permissible route time.
T_2	Maximum permissible vehicle time
v_r	Average speed of r th vehicle
P	Labour and Maintenance Costs per vehicle
DC_r	Depreciation cost of r th vehicle.

3.2.2 Objective Function: Objective function is to minimize distribution costs. Total cost of distribution is determined as follows

1) Cost of transportation

Total distance travelled by vehicle on gth route,

$$TD_g = \left[\sum_{j \in I_{\lambda_g}} d_{1j} y_{1j} + \sum_{i, j \in I_{\lambda_g}} d_{ij} y_{ij} + \sum_{j \in I_{\lambda_g}} d_{j1} y_{j1} \right] \dots\dots (1)$$

Total cost of transportation for gth route =

$$TC_g = \sum_{r=1}^{NV} \delta_g^r (TD_g \cdot K_r)$$

Therefore total cost of transportation for all the routes

$$TC_1 = \sum_{g=1}^G \sum_{r=1}^{NV} \delta_g^r (TD_g \cdot K_r) \dots\dots (2)$$

2) Labour and Maintenance Cost: Since the labour and maintenance cost is assumed to be the same for all the vehicles, the total labour and maintenance cost can be expressed as follows:

$$TC_2 = NV * P \dots\dots (3)$$

3) Depreciation Cost: Let DC_r be the depreciation cost for rth vehicle. Then the total depreciation cost is given by

$$TC_3 = \sum_{r=1}^{NV} DC_r \dots\dots (4)$$

- The total cost of distribution is the sum of transportation cost, labour maintenance and depreciation cost. Therefore,

$$\begin{aligned} \text{Total cost} &= TC_1 + TC_2 + TC_3 \\ &= \sum_{g=1}^G \sum_{z=1}^{NV} \delta_g^z (TD_g * K_z) + NV * P + \sum_{z=1}^{NV} DC_z \quad \dots (5) \end{aligned}$$

where TD_g is distance travelled by vehicle on g th route.

3.2.3 Constraints

- Except for depot, each one of other nodes is connected to one and only one other node. Mathematically this can be expressed as :

$$i) \sum_{\substack{j=2 \\ j \neq i}}^N \gamma_{ij} = 1 \quad \text{for } j = 2, 3, \dots, N \quad \dots (6)$$

$$ii) \sum_{\substack{j=2 \\ j \neq i}}^N \gamma_{ij} = 1 \quad \text{for } i = 2, 3, \dots, N \quad \dots (7)$$

- Since each route is to be assigned to only one vehicle, we obtain following constraint:

$$\sum_{z=1}^{NV} \delta_g^z = 1 \quad \text{for } g = 1, 2, \dots, G \quad \dots (8)$$

However, a vehicle can be assigned to many routes. Therefore,

$$\sum_{g=1}^G \delta_g^z = K \cdot 1 \quad \text{Where } K \text{ is an integer value} \quad \dots (9)$$

- Demand Constraint: The restriction that one route should pass through a customer and full requirement of the customer is delivered at a stretch, implies that the capacity of the

vehicle assigned to the route, on which the considered customer is, should be equal to or more than demand of that customer.

$$\text{i.e. } \sum_{z=1}^{NV} C_z \delta_{gj}^z \geq D_j \quad \text{for } j = 2, 3, \dots, N \quad \dots (10)$$

where $j \in I_{\lambda g}$

Constraints (3) & (4) imply that if r th vehicle is assigned to the route, say g th, on which the customer j is, then

$$C_r \geq D_j \quad \dots (11)$$

- 4) Capacity Constraint: If r th vehicle is assigned to g th route then capacity of r th vehicle should be equal to or more than the sum of demands of all customers on the g th route.

$$\text{i.e. } \sum_{j \in I_{\lambda g}} D_j \leq C_r \quad \dots (12)$$

$$\text{In general, } \sum_{j \in I_{\lambda g}} D_j \leq \sum_{r=1}^{NV} C_r \delta_g^r \quad \text{for } g = 1, 2, \dots, G \quad \dots (13)$$

5) Time Constraint

- 1) Route time constraint: This constraint restricts the length of the route and number of customers to be included in that route, such that delivery to each customer is made within specified time. Route time of any route is the sum of the ~~total time~~ travelled by the vehicle on the route and the total stop-off-time at all the customers on that route. Let T_1 be the maximum permissible route time. Then this constraint implies that route time of any route should not exceed T_1 .

Total distance travelled by vehicle on gth route,

$$TD_g = \left[\sum_{j \in I_{\lambda g}} d_{1j} \gamma_{1j} + \sum_{i, j \in I_{\lambda g}} d_{ij} \gamma_{ij} + \sum_{j \in I_{\lambda g}} d_{j1} \gamma_{j1} \right] \quad \dots (14)$$

If rth vehicle is assigned to gth route, i.e., $\delta_g^r = 1$ then route time constraint is

$$(TD_g / v_r) + \sum_{j \in I_{\lambda g}} t_{sj} \leq T_1 \quad \dots (15)$$

In general, route time constraint is

$$\sum_{g=1}^{NV} \delta_g^r \left[(TD_g / v_r) + \sum_{j \in I_{\lambda g}} t_{sj} \right] \leq T_1; \quad g=1, 2, \dots, G \quad \dots (16)$$

- 2) Vehicle time constraint: This constraint implies that a delivery vehicle should make all the distribution operations assigned to it within a specified time i.e., maximum permissible vehicle time, so that they are available for the next operation. Vehicle time includes the route time for the route allocated to it and loading, unloading time of vehicle at depot. Mathematically, this constraint can be expressed as,

$$\sum_{g=1}^G \delta_g^r \left[(TD_g / v_r) + \sum_{j \in I_{\lambda g}} t_{sj} + L_r \right] \leq T_2 \quad \text{for } r=1, 2, \dots, NV \quad \dots (17)$$

Where TD_g is total distance travelled by vehicle.

- 6) Node-connectivity Constraint:

$$\begin{aligned} Y_{ij} &= 1 \quad \text{if } i\text{th node is connected to } j\text{th node,} \\ &\quad \text{for } i = 1, 2, \dots, N; \quad j = 1, 2, \dots, N \\ &= 0 \quad \text{otherwise.} \end{aligned} \quad \dots (18)$$

Equations (5) through (18) represent the mathematical formulation of the route selection and vehicle assignment problem under consideration. A solution methodology for the problem is presented in the next Chapter.

CHAPTER 4

METHODOLOGY

In this chapter, the methodology for solving the problem, formulated in Chapter 3, is presented. The approach is heuristic in character and gives near optimal solution.

Methodology for the solution of the problem broadly consists of following phases:

- (1) Determination of the shortest distances between the nodes in distribution network using shortest distance model.
- (2) Selection of the optimal set of vehicles out of available vehicles.
- (3) Design of optimal routes and the optimal allocation of vehicles to the various routes by Route design model.

4.1 Shortest Distance Model

Shortest path algorithm⁽³⁰⁾ has been used to find the shortest distances between the delivery points in the distribution network. The procedure is to examine simultaneously all the routes out of the starting point i and into the terminal point j as far as their adjacent connected points and to extend further the routes which have so far covered the least distance. This process is repeated step by step until a route out of i has a delivery point on it which has already occurred on a route into j or vice-versa. All such complete routes between i and j are examined and shortest possible route between i and j is found. Similarly shortest path

distance paths for each pair of nodes are determined. Computer program for the above algorithm has been written in FORTRAN IV language.

4.2 Routes Design Model

Looking back into the mathematical formulation presented in Chapter 3, it is observed that objective function, i.e., total cost of delivery depends upon (i) total distance travelled by vehicles, i.e., the sum of distances of all the routes for distribution, and (ii) the number and types of vehicles used for distribution. For a given set of vehicles, the total delivery cost depends upon the total distance travelled by vehicles in the set. So, for a particular set of vehicles, the problem consists of designing the routes for the vehicles for minimum total distance and the allocation of the vehicles to the designed routes for minimum delivery cost. As the set of vehicles is chosen from the available vehicles for distribution, there will be few feasible sets of vehicles to be considered. Problem is solved for each set of vehicles and the one which yields best results is chosen. Main steps involved are as follows:

- (i) Choose a particular set of vehicles to be used for distribution.
- (ii) For the above chosen set of vehicles, design the routes such that the total distance is minimum. Designing of routes is carried out in three stages:
 - (a) Constructing initial routes
 - (b) Adjusting initial routes for satisfying the constraints.
 - (c) Improving the adjusted routes by refining heuristics.
- (iii) Total cost of delivery is calculated.
- (iv) Repeat the Steps (ii) and Step (iii) for various feasible set of vehicles to be used for distribution and select the best solution yielding the minimum

Next, we have to find feasible sets of vehicles which can be used for distribution.

4.2.1 Determination of feasible 'sets' of vehicles which can be used for distribution

Initially, it is assumed that each vehicle is allocated to one route only. Later on, in the refining heuristics, this assumption is relaxed and if possible and economical, one vehicle is allocated to more than one routes. With this assumption, the number of vehicles will be equal to the number of trips which naturally depend upon the capacity of the vehicles and the total delivery at all the delivery points.

In case the vehicle set comprises of vehicles of same type and capacity, then the problem is to determine optimal number of vehicles to be used for distribution. For obtaining the lower bound on the number of vehicles to be used, following formula can be used:

$$\text{Number of vehicles} = N = \sum_{j=2}^n D_j / C$$

where $D_j \rightarrow$ Load requirement at j th delivery point

$C \rightarrow$ Capacity of the vehicle

at $j = 1$, Demand is zero because it is supplying source

If N is not a whole number, it is rounded off to next higher whole number. The problem of designing the routes may be solved for several values of N and the best solution is chosen. It has been experienced by solving some test problems that usually no more than three values of N need be considered (starting with lowest possible value of N and then increasing it in steps of one) for the final solution to be obtained.

Above formula holds good only in the case of same capacity vehicles. For different capacity vehicles, the cost of delivery, in addition to number of vehicles, depends upon the type of vehicles. Therefore, in such cases, the feasible

sets of vehicles for distribution are determined and problem may be solved for each of these sets to achieve the best solution. Vehicle-set-selection can be done by one of the following strategies:

- (i) Vehicle-set-selection policy 1: Vehicles are picked from the available set of vehicles, for assignment, in descending order of their capacities.
- (ii) Vehicle-set-selection policy 2: Vehicles are picked from the available set of vehicles, for assignment, in ascending order of their capacities.
- (iii) Vehicle-set-solution policy 3: Vehicles are picked randomly from the available set of vehicles.

The minimum number of vehicles to be employed is r , such that

$$\sum_{i=1}^{r-1} C_i \leq \sum_{j=2}^n D_j$$

and

$$\sum_{i=1}^r C_i \geq \sum_{j=2}^n D_j.$$

where $D_j \rightarrow$ load requirement at j th customer

$C_i \rightarrow$ capacity of i th vehicle

Mathematically the various set selection policies can be represented as follows:

Policy I : $C_i > C_{i+1} > C_{i+2}$

Policy II : $C_i < C_{i+1} < C_{i+2}$

Policy III : C_i , selected randomly.

For each policy, problem is solved for $r+s$ vehicles, where $s = 0, 1, 2, \dots, S$; such that $S+r =$ total number of available vehicles.

4.2.2 Designing the Routes

Having determined the sets of vehicles to be used, the problem of designing the routes is solved for each of these sets as follows:

- (i) Construct the unconstrained initial routes, for minimizing the total distance travelled on the routes by vehicles.
- (ii) Adjust the initial routes for satisfying constraints, increment in total distance, due to re-arrangement of customers on routes, is kept minimum.
- (iii) Attempt to accomodate omitted customers.
- (iv) Improve the routes obtained by refining heuristics.

4.2.3 Construction of Initial Routes

Initial routes, one for each vehicle, are constructed to cover all the delivery points in the distribution network such that the sum of total distance of all the routes is minimum. While constructing initial routes, constraints are not imposed. Initial routes are developed by using Multiple travelling salesman algorithm. Multiple travelling salesman problem is the extension of single travelling salesman problem. In general, the objective of single travelling salesman problem is defined as to find a minimum cost (or distance) route for a salesman to visit each customer once and only once, starting from depot & coming back to depot. However, if the real

depot is eliminated and replaced by NV artificial depots (where NV is the number of vehicles used for distribution), all located in same position, then problem of constructing initial routes is similar to multiple travelling salesman problem and reads^{as} 'Given NV vehicles and NC customers, find NV routes such that every customer is visited exactly once by exactly one vehicle, so that the total distance travelled by the vehicles is minimum.' An efficient algorithm for solving such problem is M-salesman travelling salesman algorithm⁽¹⁹⁾. Initial routes have been obtained by this algorithm as follows.

As stated above, real depot is replaced by NV artificial depots. Thus,

$$NN = NC + NV = (N-1) + (NV) = N + NV - 1$$

where N is total number of nodes in original network

NN is total number of nodes after replacement.

NV is number of vehicles.

The new distances $[C_{ij}]$ are obtained from the original distances $[d_{ij}]$ by augmenting the matrix $[d_{ij}]$ with $(NV-1)$ new rows and columns, where each new row and column is a duplicate of the first row and column of the matrix $[d_{ij}]$ (because first row and column correspond to depot). All other new elements of the augmented matrix are set to infinity.

Using the notations used in Chapter 3, the problem for constructing initial routes can be structured similar to Miller-Tucker-Zemlin (27)'s formulation. Thus

$$\min Z = \sum_{i=1}^{NN} \sum_{j=1}^{NN} C_{ij} y_{ij} \quad \dots\dots (1)$$

where Z is the total distance of all the routes.

Subject to

$$\sum_{i=1}^{NN} y_{ij} = 1, \quad j = 1, 2, \dots, NN$$

$$\sum_{j=1}^{NN} y_{ij} = 1, \quad i = 1, 2, \dots, NN \quad \dots\dots (2)$$

$$y_{ij} = 0 \text{ or } 1 \text{ for all } i, j \quad \dots\dots (3)$$

$$x_i - x_j + \left[\frac{N}{NV} \right] y_{ij} \leq \left[\frac{N}{NV} \right] + NV - 2 \quad \dots\dots (4)$$

for all $i \neq j$ and $i, j \notin I_0, I_0 = (1, 2, \dots, NV)$

The variables x_i and x_j are arbitrary real numbers which satisfy the constraint (4). The braces $[.]$ denote the largest integer not to exceed the value within the braces.

In above formulation, Equations (1), (2), (3) represent assignment problem formulation. The constraints (4) are the loop constraints which block the formation of infeasible subtours. Subtour is feasible only and only if it contains at least one artificial depot.

Stated in broad terms, the algorithm works as follows: An assignment problem with constraints (2) and (3) is solved. If the solution satisfies constraints (4), solution obtained, i.e., the initial routes constructed are optimal. If one or more of the constraints (4) is violated, a subset of the constraints (4) is implicitly introduced by setting certain elements of the distance matrix to infinity. The new problem is another assignment problem, which is solved and so on.

Hence, the algorithm, for generating initial routes, solves a sequence of assignment problems, which ends when the solution to one of the problems satisfies all the constraints (2), (3) and (4). The sequence of problems is defined in such a way as to assure that the terminal solution is optimal.

Briefly, the steps of the algorithm are as follows:

- Step 1: Solve the associated assignment problem. If all subtours are feasible - terminate - the solution is optimal. If not, set Z_{LB} equal to the value of assignment problem. Construct a feasible solution by initial heuristics, set Z_{UB} (upper bound) equal to the value of the feasible solution and go to Step 2.
- Step 2: Locate the shortest infeasible subtour in that assignment problem solution which defines Z_{LB} . Generate and solve k subproblems, one for each arc in the infeasible subtour. If the value of a subproblem $Z \geq Z_{UB}$, delete it from the set of subproblems, S , to be considered further. If $Z \leq Z_{UB}$ and the subproblem solution is feasible, redefine Z_{UB} , delete the subproblem, continue.
- Step 3: If set S is empty, terminate, otherwise scan the set S for that problem such that $Z = \min_{i \in S} Z_i$ and set $Z_{LB} = Z$. If $Z_{LB} = Z_{UB}$ - terminate - otherwise go to Step 2.

4.2.4 Adjusting the initial routes for satisfying the constraints

In the previous section, unconstrained initial routes were obtained for the minimum total distance. These initial routes are now adjusted, to satisfy the constraints, by re-arranging the customers on the routes. Re-arrangement of the customers on the routes involves the increment in the total

distance of initial routes. Proposed algorithm, for adjustment of initial routes, attempts to re-arrange the customers on routes for adjustment, such that the increment in total distance of initial routes is minimized.

Algorithm starts with allocating the vehicles to the initial routes by following policies:

- (a) Vehicle allocation policy 1: Allocate vehicles to routes in random order.
- (b) Vehicle allocation policy 2: Allocate vehicles to routes in descending order of capacities, i.e., maximum capacity vehicle is allocated to first route and minimum capacity vehicle to last route.
- (c) Vehicle allocation Policy 3: Allocate vehicles to routes in ascending order of capacities.

For each policy, allocation of vehicles to routes causes some routes to be overloaded* and some to be underloaded*. An attempt is made to accomodate customers from the overloaded routes on underloaded routes for minimal increment in distance due to reshuffling of customers. All the ^{three} ~~tree~~ policies listed above, are tested and the policy giving the best solution is chosen. For each of the policies, the routes are adjusted

-
- *(1) Overloaded Route: If the total demand of customers on a route is more than capacity of vehicle allocated to it, is more, then route is called an overloaded route.
 - (2) Underloaded Route: If total demand of customers on a route is less than capacity of vehicle allocated, then route is called an underloaded route.

as follows:

Step 1: Firstly the proposed algorithm lists out all overloaded and/or overtimed routes* and adjusts one such route at a time. An immediate problem arises as to which overloaded route should be considered, because the order of presentation of overloaded routes might affect the solution. In order to observe the affect of order of presentation of overloaded routes for adjustment to algorithm, the following three route policies have been considered:

Route Policy 1: Overloaded route is selected randomly out of the overloaded routes.

Route Policy 2: Most overloaded route is selected first

Route Policy 3: Least overloaded route is selected first.

Overloaded route, obtained by a particular route policy, is adjusted as follows.

Step 2: Suppose the overloaded route to be considered for adjustment is OVR_1 . Each customer on route OVR_1 is considered to be discarded from route OVR_1 and to be accomodated in some of other routes. Suppose customer A_1 is considered to be discarded from route OVR_1 . This customer can be accomodated in any of other unadjusted routes and also to already adjusted routes if inclusion of it does not violate the capacity and time constraint of that adjusted route. Now a search is made to find the pair of linked nodes B_1 and C_1 on any of these permissible routes for accomodating A_1 , such that new connections of A_1 with B_1 and C_1 involve the minimum distance increment MD_1 . MD_1 , B_1 and C_1 corresponding to discarded customer

* Overtimed route is the route for which route time is more than specified maximum route time.

A_1 are noted and customer A_1 is restored to route OVR_i . Then another customer A_2 is considered. Similarly for all the customers A_j on route OVR_i , search is made to find minimum distance increment MD_j and corresponding new connections for A_j , i.e., the pair of linked nodes B_j and C_j .

Step 3:

In this step, a combination of customers on route OVR_i is sorted such that (i) removal of these customers adjusts the overloaded route under consideration, (ii) sum of minimum distance increments of discarded customers is minimized. This problem for sorting the best combination of customers, has been tackled by zero-one programming. Problem can be expressed in mathematical form as follows:

Let J - set of customers on overloaded route OVR_i
 MD_j - minimum distance increment involved with removal of j th customer, where $j \in J$.

$OVC(i)$ - the overloaded quantity on route OVR_i .

$OVT(i)$ - the route time exceeded for route OVR_i

D_j - demand of j th customer, where $j \in J$

t_j - route time saving due to removal of j th customer from route OVR_i .

X_j - 0,1 variables.

$X_j = 1$ if j th customer is discarded
 $= 0$ otherwise.

The combination of customers is to be chosen from the set J so as to,

$$\text{minimize } \sum_{j \in J} MD_j X_j \quad \dots\dots (1)$$

$$\text{subject to } \sum_{j \in J} t_j X_j \geq OVR(i)$$

$$\sum_{j \in J} D_j X_j \geq OVC(i) \quad \dots\dots (2)$$

$$X_j = 0 \text{ or } 1 \quad \dots\dots (3)$$

Zero-one programming solves the above problem and gives the optimal combination of customers to be discarded from route OVR_i in order to adjust it. The discarded customers are connected to their new connections B_j and C_j as found in Step 2. If any customer j on route OVR_i can't be included in any other route, MD_j is set to infinity so that this does not come into the solution giving the combination of customers to be discarded. Such customers are kept aside and listed as omitted customers.

Thus Step 3 adjusts the overloaded route OVR_i . This route is now called adjusted route for capacity and time constraint and in further adjustments, customer can be accommodated to this route if and only if that customer does not violate the capacity and time constraints of this route.

Repeat the Step (1) through Step (3) till all the routes are adjusted for capacity and time constraints. Omitted customers are also listed to be considered in next section.

4.2.5 Consideration of Ommitted Customers

Next, an attempt is made to accomodate the ommitted customers into some of the routes. Each ommitted customer is taken in turn and every route is inspected in order to determine whether by removing another customer, the ommitted one could be accepted; the customer removed is then fitted, if possible, into another route. If there is no customer left unassigned, we go ahead for improving the solution by refining heuristics. However, if some ommitted customers remain, we go back to Section 4.2.2 for considering another set of vehicles to be used for distribution.

4.2.6 Refining Heuristics

Routes have been improved further for reducing total delivery costs by the following refining heuristics.

(1) In first heuristic, each customer is considered in turn and the possibilities of moving him to all other positions in the same or another route are considered. He is moved to the position found for which the total distance is reduced and no constraints are violated.

(2) Second heuristic also attempts to reduce total distance. A customer from one route is placed in another route, if a customer from the second route could be inserted elsewhere in the system to reduce total distance. This procedure was developed because it was felt that the first heuristic might fail to place a customer in a route where this was desirable because of violation of capacity constraint. In such cases, the room could have been made in the route by removing another customer from it by this heuristic.

(3) Lastly, a refining heuristic is applied for reducing the number of vehicles in use and hence reducing the total delivery cost. If some vehicles return to depot (after distribution) after only a few hours, it might be desirable to give a second trip to one or more vehicles if second trip can be completed within maximum allowed vehicle time. This procedure examines every pair of routes and searches for the pairs whose combined duration, after allowing for time to reload the vehicle, is below the maximum permitted time. This process does not reduce the number of distinct routes, therefore no savings in terms of total distance involved occur. But if two routes are combined and allocated to one vehicle, if possible, a vehicle is saved which in turn reduces the total delivery cost.

The computer programmes have been developed for all the algorithms discussed above. The computer package has been written in FORTRAN IV language and has been run on IBM 7044.

COMPARISON OF PROPOSED MODEL WITH CLARKE & WRIGHT'S METHOD

In this chapter, the proposed model has been compared with the Clarke & Wright's (6) method for solving the vehicle dispatching problem. Nine test problems have been structured and solved by both the methods and the results obtained have been compared. Since Clarke & Wright's method does not take care of time constraint, the time constraint has not been considered in the test problems. The various costs of distribution are assumed to be the same for all the test problems. The various costs of distribution are tabulated in Table 5.1. The data on shortest distance between customers, customers' demand and the capacities of the vehicles for the various structured problems are given in tables 5.2 through 5.10. The shortest distance matrix has been generated by generating psuedo - random numbers between 0 and 1. The psuedo - random numbers have been generated by using the function RNDY5*. The shortest distance between the nodes i & j is determined using the relationship $(d_{ij}) = (A * \text{RNDY5})$ where A is some arbitrary chosen real number. For each problem a different value of A has been selected. Input data and results obtained from the Clarke & Wright's method and proposed model, for each test problem are given in Tables 5.2 through 5.10. Results indicate that in all the test problems proposed model has performed better in terms of total cost of delivery. A summary of the results obtained by the two methods is given in Table 5.11.

The results have been summarized in following paragraphs. The results indicate that

- i) For each problem the total distance travelled by vehicles

* Note: RNDY5 is a built in function in IBM/7044.

to satisfy the demands of the set of customers considered in problem, is less in the case of the routes obtained by proposed method.

- ii) The number of vehicles required for distribution by proposed method has been observed to be either equal to or less than found by the Clarke & Wright's method. In test problem numbers 2,3 and 9, the saving of a vehicle has been observed with proposed method.
- iii) The cost of transportation is less with use of proposed method in all the test problems. Percentage saving in the cost of transportation with proposed method over Clarke & Wright's method varies from 6% (for test problem 1) to 32% (for test problem 5).
- iv) Total cost of delivery has been observed to be less in case of distribution by proposed method than that in case of the Clarke & Wright's method in all the test problems. Percentage saving in the total cost of delivery varies from 2% (for test problem 1) to 23% (for test problem 2).
- v) Computational efficiency of the two methods has been compared in terms of execution time and computer memory needed. Table 5.11 shows the execution time for both the methods. Execution time for the proposed method has been observed to be higher than that for the Clarke & Wright's method for all the test problems. Computer memory requirement is also more for the proposed method than that required for Clarke & Wright's method.

To conclude, the proposed method is not computationally as efficient as Clarke & Wright's method; but this is more than made up by the fact that the proposed method results in considerable higher savings in cost to the tune of 10 to 20% and hence, is justifiably preferable.

Table 5.11) Operations Characteristics of vehicles

- i) Average speed = 20 Km./Hour
- ii) Consumption of fuel (petrol) 0.25 litre/km.
- iii) Fuel cost = Rs. 3.27/litre

2) Cost of transportation = Rs. 0.81/Km.

3) Maintenance cost per vehicle = Rs. 400 per month

4. Depreciation cost :

Initial cost of vehicle = Rs. 80,000

Depreciation rate (straight line method) = 10% per year.

Depreciation cost per vehicle = Rs. 666.67 per month.

5) Labour cost :

Salary to driver = Rs. 200/- per month

Salary to helper = Rs. 175/- per month

Salary to Route clerk = Rs. 250/- per month.

Total Labour cost per vehicle = Rs. 800/- per month.

TEST PROBLEM 1

INPUT INFORMATIONS

NO. OF CUSTOMERS = 10
 DISTANCE MATRIX GENERATED BY USING RNDY5
 $B(I, J) = \text{IFIX}(A \cdot \text{RNDY5}(Y5))$
 $A = 17.5$
 DEMANDS FOR CUSTOMERS
 10 9 15 7 6 12 11 10 9 6
 CAPACITY OF VEHICLES = 50

RESULTS

CLARKE AND WRIGHT METHOD

ROUTE	UNUSED CAPACITY	ROUTE PATH
1	0	1 6 2 3 5 11 7 1
2	5	1 8 4 10 9 1

OPTIMAL NO. OF VEHICLES = 2
 TOTAL DISTANCE = 67

COST OF TRANSPORTATION = 1641.50
 MAINTENANCE, DEPRECIATION AND LABOUR COST = 3733.32
 TOTAL COST = 5374.82

PROPOSED METHOD

ROUTE	UNUSED CAPACITY	ROUTE PATH
1	4	1 3 9 7 10 6 1
2	1	1 4 2 5 11 8 1

BEST ROUTE POLICY IS 1

OPTIMAL NO. OF VEHICLES = 2
 TOTAL DISTANCE = 63

COST OF TRANSPORTATION = 1543.50
 MAINTENANCE, DEPRECIATION AND LABOUR COST = 3733.32
 TOTAL COST = 5276.82

TEST PROBLEM 2

INPUT INFORMATION

NO. OF CUSTOMERS = 13

DISTANCE MATRIX GENERATED BY USING RNDY5

 $B(1, J) = \text{IFIX}(A \cdot \text{RNDY5}(Y5))$

A = 10.0

DEMANDS FOR CUSTOMERS

23 25 24 18 25 20 24 22 18 19 20 17 26

CAPACITY OF VEHICLES = 100

RESULTS

CLARKE AND WRIGHT METHOD

ROUTE	UNUSED CAPACITY	ROUTE PATH
1	76	1 4 1
2	15	1 6 9 5 7 1
3	13	1 8 11 14 10 1
4	15	1 12 2 13 3 1

OPTIMAL NO. OF VEHICLES = 4

TOTAL DISTANCE= 53

COST OF TRANSPORTATION = 1298.50

MAINTENANCE, DEPRECIATION AND LABOUR COST= 7466.64

TOTAL COST= 8765.14

PROPOSED METHOD

ROUTE	UNUSED CAPACITY	ROUTE PATH
1	12	1 12 8 5 14 1
2	7	1 3 2 7 6 1
3	0	1 11 13 4 9 10 1

BEST ROUTE POLICY IS 1

OPTIMAL NO. OF VEHICLES = 3

TOTAL DISTANCE= 48

COST OF TRANSPORTATION = 1176.00

MAINTENANCE, DEPRECIATION AND LABOUR COST= 5599.98

TOTAL COST= 6775.98

TEST PROBLEM 3

INPUT INFORMATIONS

NO. OF CUSTOMERS = 15
 DISTANCE MATRIX GENERATED BY USING RNDY5
 $B(I,J) = \text{IFIX}(A \cdot \text{RNDY5}(Y5))$

$A = 22.5$

DEMANDS FOR CUSTOMERS

15 12 11 12 8 18 17 11 12 10 9 18 17 8 10
 CAPACITY OF VEHICLES = 50

RESULTS

CLARKE AND WRIGHT METHOD

ROUTE	UNUSED CAPACITY	ROUTE PATH
1	6	1 6 7 13 1
2	5	1 8 14 4 1
3	9	1 9 16 15 10 1
4	40	1 11 1
5	2	1 12 5 3 2 1

OPTIMAL NO. OF VEHICLES = 5
 TOTAL DISTANCE = 130

COST OF TRANSPORTATION = 3185.00
 MAINTENANCE, DEPRECIATION AND LABOUR COST = 9333.30
 TOTAL COST = 12518.30

PROPOSED METHOD

ROUTE	UNUSED CAPACITY	ROUTE PATH
1	7	1 15 14 13 1
2	0	1 10 3 7 6 1
3	3	1 8 4 11 12 1
4	2	1 2 16 5 9 1

BEST ROUTE POLICY IS 3

OPTIMAL NO. OF VEHICLES = 4
 TOTAL DISTANCE = 108

COST OF TRANSPORTATION = 2646.00
 MAINTENANCE, DEPRECIATION AND LABOUR COST = 7466.64
 TOTAL COST = 10112.64

TEST PROBLEM 4

INPUT INFORMATIONS

NO. OF CUSTOMERS = 18

DISTANCE MATRIX GENERATED BY USING RNDY5

 $B(I,J) = \text{IFIX}(A \cdot \text{RNDY5}(Y5))$

A = 25.0

DEMANDS FOR CUSTOMERS

30 60 70 40 35 32 48 23 32 41 35 58 35 31 37 42
 44 35

CAPACITY OF VEHICLES = 175

RESULTS

CLARKE AND WRIGHT METHOD

ROUTE	UNUSED CAPACITY	ROUTE PATH
1	2	1 10 4 8 9 1
2	134	1 1 1
3	6	1 13 7 18 6 1
4	2	1 15 17 2 12 14 1
5	3	1 16 3 5 19 1

OPTIMAL NO. OF VEHICLES = 5

TOTAL DISTANCE= 170

COST OF TRANSPORTATION = 4165.00

MAINTENANCE, DEPRECIATION AND LABOUR COST= 9333.30

TOTAL COST= 13498.30

PROPOSED METHOD

ROUTE	UNUSED CAPACITY	ROUTE PATH
1	12	1 13 10 15 17 1
2	22	1 4 8 19 1
3	2	1 9 2 18 6 11 1
4	8	1 12 7 5 3 1
5	103	1 16 14 1

BEST ROUTE POLICY IS 2

OPTIMAL NO. OF VEHICLES = 5

TOTAL DISTANCE= 152

COST OF TRANSPORTATION = 3724.00

MAINTENANCE, DEPRECIATION AND LABOUR COST= 9333.30

TOTAL COST= 13057.30

TEST PROBLEM 5

INPUT INFORMATIONS

NO. OF CUSTOMERS = 20

DISTANCE MATRIX GENERATED BY USING RNDY5

 $B(I,J) = \text{IFIX}(A \cdot \text{RNDY5}(Y5))$

A = 27.5

DEMANDS FOR CUSTOMERS

25	18	16	23	30	12	20	18	20	15	20	15	17	23	21	20
20	15	16	16												

CAPACITY OF VEHICLES = 100

RESULTS

CLARKE AND WRIGHT METHOD

ROUTE	UNUSED CAPACITY	ROUTE PATH
1	2	1 4 16 20 11 9 7 1
2	2	1 12 21 2 17 14 1
3	12	1 13 8 5 6 1
4	4	1 10 15 3 10 19 1

OPTIMAL NO. OF VEHICLES = 4

TOTAL DISTANCE = 176

COST OF TRANSPORTATION = 4312.00

MAINTENANCE, DEPRECIATION AND LABOUR COST = 7466.64

TOTAL COST = 11778.64

PROPOSED METHOD

ROUTE	UNUSED CAPACITY	ROUTE PATH
1	2	1 13 11 9 17 6 1
2	2	1 20 3 2 15 4 1
3	12	1 14 10 21 19 12 1
4	4	1 7 16 8 5 18 1

BEST ROUTE POLICY IS 2

OPTIMAL NO. OF VEHICLES = 4

TOTAL DISTANCE = 119

COST OF TRANSPORTATION = 2915.50

MAINTENANCE, DEPRECIATION AND LABOUR COST = 7466.64

TOTAL COST = 10382.14

TEST PROBLEM 6

INPUT INFORMATION

NO. OF CUSTOMERS = 22

DISTANCE MATRIX GENERATED BY USING RNDY5

 $B(I,J) = \text{IFIX}(A \cdot \text{RNDY5}(Y5))$

A = 15.0

DEMANDS FOR CUSTOMERS

13	14	16	14	8	14	12	15	14	10	14	8	14	12	12	15
9	10	15	11	14	15										

CAPACITY OF VEHICLES = 50

RESULTS

CLARKE AND WRIGHT METHOD

ROUTE	UNUSED CAPACITY	ROUTE PATH
1	0	1 2 11 17 15 1
2	7	1 3 22 9 1
3	2	1 5 10 13 8 1
4	3	1 12 19 6 23 1
5	1	1 16 7 18 14 1
6	8	1 20 4 21 1

OPTIMAL NO. OF VEHICLES = 6

TOTAL DISTANCE= 124

COST OF TRANSPORTATION = 3038.00

MAINTENANCE, DEPRECIATION AND LABOUR COST= 11199.96

TOTAL COST= 14237.96

PROPOSED METHOD

ROUTE	UNUSED CAPACITY	ROUTE PATH
1	6	1 7 10 4 1
2	2	1 13 8 14 5 1
3	0	1 21 20 19 12 1
4	3	1 3 17 11 6 1
5	2	1 16 18 15 9 1
6	8	1 2 23 22 1

BEST ROUTE POLICY IS 1

OPTIMAL NO. OF VEHICLES = 6

TOTAL DISTANCE= 110

COST OF TRANSPORTATION = 2695.00

MAINTENANCE, DEPRECIATION AND LABOUR COST= 11199.96

TOTAL COST= 13894.96

TEST PROBLEM 7

INPUT INFORMATIONS

NO. OF CUSTOMERS = 25

DISTANCE MATRIX GENERATED BY USING RNDY5

 $B(I,J) = \text{IFIX}(A \cdot \text{RNDY5}(Y5))$

A = 20.0

DEMANDS FOR CUSTOMERS

30	60	70	40	35	32	48	23	32	41	35	58	35	31	37	42
44	35	25	28	28	32	28	31	32							

CAPACITY OF VEHICLES = 200

RESULTS

CLARKE AND WRIGHT METHOD

ROUTE	UNUSED CAPACITY	ROUTE PATH
1	19	1 6 24 7 21 19 9 1
2	13	1 8 16 10 4 1
3	18	1 12 3 20 23 2 1
4	17	1 14 17 15 25 18 1
5	1	1 26 11 5 13 22 1

OPTIMAL NO. OF VEHICLES = 5

TOTAL DISTANCE= 162

COST OF TRANSPORTATION = 3969.00

MAINTENANCE, DEPRECIATION AND LABOUR COST= 9333.30

TOTAL COST= 13302.30

PROPOSED METHOD

ROUTE	UNUSED CAPACITY	ROUTE PATH
1	41	1 12 6 22 2 25 1
2	6	1 8 19 9 3 24 1
3	0	1 10 5 13 4 1
4	10	1 17 23 20 21 7 15 1
5	11	1 14 26 18 11 16 1

BEST ROUTE POLICY IS 2

OPTIMAL NO. OF VEHICLES = 5

TOTAL DISTANCE= 126

COST OF TRANSPORTATION = 3087.00

MAINTENANCE, DEPRECIATION AND LABOUR COST= 9333.30

TOTAL COST= 12420.30

TEST PROBLEM 8

INPUT INFORMATION

NO. OF CUSTOMERS = 28
 DISTANCE MATRIX GENERATED BY USING RNDY5
 $B(I, J) = \text{IFIX}(A \cdot \text{RNDY5}(Y5))$
 $A = 20.0$

DEMANDS FOR CUSTOMERS

13 14 16 14 8 14 12 15 14 10 14 8 14 12 12 15
 9 10 15 11 14 15 15 12 11 12 13 18
 CAPACITY OF VEHICLES = 55

RESULTS

CLARKE AND WRIGHT METHOD

ROUTE	UNUSED CAPACITY	ROUTE PATH
1	14	1 4 11 24 1
2	1	1 5 29 10 13 1
3	0	1 12 3 22 2 1
4	5	1 16 26 23 15 1
5	2	1 18 20 9 7 1
6	2	1 25 21 8 19 6 1
7	1	1 27 14 17 28 1

OPTIMAL NO. OF VEHICLES = 7
 TOTAL DISTANCE = 205

COST OF TRANSPORTATION = 5022.50
 MAINTENANCE, DEPRECIATION AND LABOUR COST = 13066.62
 TOTAL COST = 18089.12

PROPOSED METHOD

ROUTE	UNUSED CAPACITY	ROUTE PATH
1	2	1 18 14 13 11 8 1
2	2	1 21 24 17 25 1
3	3	1 7 9 20 6 1
4	3	1 4 16 26 2 1
5	2	1 22 23 15 27 1
6	9	1 10 29 12 1
7	4	1 5 19 3 28 1

BEST ROUTE POLICY IS 3

OPTIMAL NO. OF VEHICLES = 7
 TOTAL DISTANCE = 142

COST OF TRANSPORTATION = 3479.00
 MAINTENANCE, DEPRECIATION AND LABOUR COST = 13066.62
 TOTAL COST = 16545.62

TEST PROBLEM 9

INPUT INFORMATION

NO. OF CUSTOMERS = 30

DISTANCE MATRIX GENERATED BY USING RNDY5

 $B(I, J) = \text{IFIX}(A \cdot \text{RNDY5}(Y5))$

A = 25.0

DEMANDS FOR CUSTOMERS

20	24	25	20	14	19	14	20	22	20	18	15	17	23	21	17
16	19	15	18	20	19	24	16	18	17	15	25	16	19		

CAPACITY OF VEHICLES = 75

RESULTS

CLARKE AND WRIGHT METHOD

ROUTE	UNUSED CAPACITY	ROUTE PATH
1	12	1 4 21 2 1
2	2	1 12 9 5 13 1
3	7	1 14 8 22 27 1
4	10	1 16 3 11 1
5	12	1 18 17 28 20 1
6	4	1 19 6 10 25 1
7	3	1 23 30 26 7 1
8	9	1 24 15 31 1
9	50	1 29 1

OPTIMAL NO. OF VEHICLES = 9

TOTAL DISTANCE= 229

COST OF TRANSPORTATION = 5610.50

MAINTENANCE, DEPRECIATION AND LABOUR COST= 16799.94

TOTAL COST= 22410.44

PROPOSED METHOD

ROUTE	UNUSED CAPACITY	ROUTE PATH
1	3	1 2 20 7 12 1
2	4	1 19 22 28 17 1
3	0	1 8 3 16 18 1
4	8	1 4 21 24 1
5	2	1 25 10 5 13 1
6	2	1 23 27 9 14 1
7	2	1 11 26 30 31 1
8	13	1 29 6 15 1

BEST ROUTE POLICY IS 2

OPTIMAL NO. OF VEHICLES = 8

TOTAL DISTANCE= 184

COST OF TRANSPORTATION = 4508.00

MAINTENANCE, DEPRECIATION AND LABOUR COST= 14933.28

TOTAL COST= 19441.28

TABLE 5.11

COMPARISON OF RESULTS - SUMMARY

Method I - Clarke & Wright's Method

Method II Proposed method

Test Problem	No. of Customers	Total Distance		No. of vehicles required		Cost of transportation		Total cost of delivery		Computation time* (Secs.)	
		I	II	I	II	I	II	I	II	I	II
1	10	67	63	2	2	1641.50	1543.50	5374.32	5276.32	9	22
2	13	53	48	4	3	1296.50	1176.00	8765.14	6775.98	12	27
3	15	130	103	5	4	3185.00	2646.00	12518.30	10112.64	14	35
4	18	170	152	5	5	4165.00	3724.00	13498.30	13057.30	15	40
5	20	176	119	4	4	4312.00	2915.00	11778.64	10332.14	18	44
6	22	124	110	6	6	3038.00	2695.00	14237.96	13894.96	19	43
7	25	162	126	5	5	3969.00	3087.00	13302.30	12420.30	21	51
8	28	205	142	7	7	5022.50	3479.00	18089.12	16545.62	25	57
9	30	229	184	9	8	5610.50	4503.00	22410.44	19441.28	28	64

* Execution time only.

CHAPTER VIVEHICLE DISPATCHING FOR KANPUR SAHAKARI MILK BOARD - A CASE STUDY

6.1 The proposed model has been used for the development of distribution routes and vehicle dispatching strategies for Kanpur Sahakari Milk Board which is engaged in distribution of milk products in Kanpur City. The company has a wide distribution network and a fleet of delivery trucks. A brief description of the operations of Kanpur Sahakari Milk Board (KSMB). is given in the following paragraphs:

6.1.1 Procurement Raw milk is collected at various collection centres having milk potentiality. At some of these collection centres where the milk potentiality is high, company has got its chilling centres for preserving the collected milk. Presently three company owned tankers and six hired private vehicles transport this collected milk to the Dairy for processing.

6.1.2 Processing: Procured raw milk and imported milk powder is processed to yield pasteurized milk products namely Milk, butter, ghee and cream etc. Processing is done for preparing toned, double toned and skimmed milk etc. having different fat percentages. Processed milk is bottled in half-litre capacity bottles and kept in cold storage, ready for distribution.

6.1.3 Distribution: The Company has a wide distribution network and a fleet of delivery trucks. The milk products are distributed to the general public through the agents at various delivery centres. In other words, Distribution Channel followed is Producer to retailer to consumer. Company is distributing the products twice a day (morning & evening) to about 250 agents in Kanpur city who sell them to public. Therefore, so far the company's distribution

system is concerned, agents are the customers. Main products to be delivered are milk and butter. For Ghee, there are only two delivery centres, one at the dairy itself and other at Super Market, Kanpur. There are just two or three deliveries per month to Super Market, therefore the distribution of Ghee has not been scheduled in the regular distribution system. Presently, the company is engaging Nine delivery trucks for distribution, seven out of them are bigger (Capacity of 4000 bottles) and two smaller (capacity of 1600 bottles). All the nine trucks are allocated to 9 routes in the morning shift and six trucks (5 bigger and 1 smaller) trucks for 6 routes in evening shift, demand in evening being lesser.

Delivery trucks are loaded with crates (each containing 20 bottles) at the loading centre. The loaded truck is accompanied by two helpers, one route clerk and obviously one driver for the distribution of products. Helpers load and unload the crates at the delivery points and depot. Route clerk is responsible for the proper distribution and money transaction etc. Full delivery to each customer is being made simultaneously. At each customer point, the crates of returned empty bottles are loaded in truck. After delivering to every customer on the routes, trucks return to the dairy (depot) and all the crates of empty bottles in truck are unloaded. This completes the distribution cycle.

For conducting the case study, various data need to be collected as an input information to the model. Following section discusses about the data collection for the use of present study.

6.2 Data Collection: The strategy used for the collection of data has been discussed in this section. Mainly five set of data are required viz.:

- a) Distances between the delivery points ,
- b) Demands at various delivery points,
- c) Operating characteristics of available delivery vehicles,
- d) Costs involved in distribution.

Before going ahead, it is opportune to discuss some procedural simplifications made, for making the study convenient, as follows:

6.2.1 Aggregation of delivery points

The number of delivery points at which milk products are distributed in Kanpur City is around two hundred and fifty. Because of computational difficulties and limited computer memory, it is not possible to consider them individually. Therefore, delivery points have been grouped. A group of customers are supposed to be supplied from a single delivery point. Firstly the delivery points in a locality have been grouped and each group has been represented by a delivery point in that locality. These delivery points have been plotted on the map of Kanpur City. These delivery points turned out to be 88 in number. Since the proposed model can handle about 30 customers because of computer storage limitations on IBM/7044, further grouping of these delivery points was needed. The plotted delivery points forming the clusters have been grouped first. The delivery points which do not form the clusters have been grouped, based on proximity criterion. The delivery points within a diameter of 1.5 km have been considered to be at a single delivery point. By this proximity criterion, twenty three groups have been formed. But it was observed that the number of individual delivery points in some groups, which were in densely populated area, was quite high as compared to that in thinly populated area. Therefore, second criterion was used for grouping. This criterion groups the individual points in densely populated area within diameter of 1 km which yields the number of delivery points in each group more or less same i.e., between 8 to 10 delivery points, in each group. Thus, in nutshell, the criteria used for aggregation of delivery points can be spelled out as 'the delivery points within a diameter of 1.5 km in the densely populated area and delivery points within 1.0 km in a thinly populated area are considered to be at a single delivery point which has been named as zonal delivery point.' Above procedure of aggregation of delivery points yields Twenty seven zonal delivery points which have been considered as the nodes in the distribution network.

for the present case study. These nodes have been listed in table 6.1. The total requirement of individual delivery points group, named as zone is represented as the load at zonal delivery point of that zone. The total delivery to the delivery in any zone is supposed to be delivered at the zonal delivery point.

6.2.2 Milk as the only product to be delivered: In the present distribution system, among the milk products which are distributed, milk has been considered as the main product for distribution. The ghee and butter are needed in smaller quantities and are being distributed at fewer delivery centres. Moreover, the capacity contribution of these products to the vehicles for distribution being very small, these products have not been considered for distribution. This assumption leave milk as the only product for distribution in our study.

6.3 The strategies used for the collection of data are outlined in the following paragraphs:

6.3.1 Distances between the nodes in distribution network: As discussed in Chapter 3, the shortest distances between the nodes are required as an input data to the model. Shortest distances are obtained from direct linked distances as discussed in Chapter 4, by shortest path algorithm. Therefore, data have been collected to prepare direct linked distance matrix showing the distances of direct path between every pair of nodes. For collecting these data, the zonal delivery points and milk depot are plotted on the road map of the Kanpur city. The road distances between each pair of zonal delivery points, which are connected by road are determined. If there are many possible direct links between two zonal delivery points, the shortest direct link is considered. The unit of distance matrix is one fourth of a kilometer. Wherever there is no direct link between two delivery points distance between them has been assumed as infinity. Distance matrix has been shown in Table 6.2(a). Shortest distance matrix, as computed by shortest path algorithm, has been shown in Table 6.2(b).

TABLE 6.1

<u>NODE</u>	<u>ZONE-NAME</u>
1	Milk Board
2	Khapra Mohal
3	Generalganj
4	Ram Narain Bazar
5	Chowk
6	Birhana Road
7	Cantonment
8	Latouch Road
9	Chamanganj
10	Anwarganj Station
11	Faithfulganj
12	Govindnagar (East)
13	Govindnagar (West)
14	Ordinance factory
15	Shastrinagar
16	Lajpat Nagar
17	L.L.R. Hospital
18	IIT
19	Aryanagar
20	Nawabganj
21	Azadnagar
22	Gwaltoli (South)
23	Gwaltoli (North)

<u>NODE</u>	<u>ZONE NAME</u>
24	Fazalganj
25	Jawaharnagar
26	Kidwainagar
27	Civil Lines
28	Parade

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TABLE 6.2 (b)

SHORTEST DISTANCE MATRIX

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	0	37	32	33	31	36	36	27	22	18	32	6	6	24	22	17	25	65	26	37	44	30	35	10	18	14	30	27
2	37	0	8	7	10	6	8	10	20	19	8	37	37	47	41	34	33	73	25	36	43	20	21	30	22	24	16	13
3	32	8	0	4	4	5	16	5	12	14	12	32	32	42	35	28	25	65	17	28	35	12	13	22	14	25	12	5
4	33	7	4	0	3	4	15	8	13	17	13	35	35	45	36	29	26	66	18	29	36	13	14	23	15	28	11	6
5	31	10	4	3	0	7	18	7	11	16	10	33	34	44	34	27	24	64	16	27	34	11	12	21	13	27	8	4
6	36	6	5	4	7	0	14	9	16	18	9	36	36	46	39	32	29	69	21	32	39	16	17	26	18	27	12	9
7	36	8	16	15	18	14	0	18	28	26	12	37	42	54	48	41	40	80	33	44	51	28	29	38	30	22	24	21
8	27	10	5	8	7	9	18	0	10	9	17	27	27	37	31	24	23	63	22	33	40	17	18	25	19	20	15	10
9	22	20	12	13	11	16	28	10	0	10	21	22	24	38	32	25	22	62	14	25	32	14	15	18	12	25	14	7
10	18	19	14	17	16	18	26	9	10	0	14	18	18	28	22	15	14	54	18	26	33	24	25	16	12	20	24	17
11	32	8	12	13	10	9	12	17	21	14	0	32	32	42	36	29	28	68	26	37	44	21	22	30	23	18	18	14
12	6	37	32	35	33	36	37	27	22	18	32	0	10	28	18	18	26	66	32	38	45	36	37	16	24	15	36	29
13	6	37	32	35	34	36	42	27	24	18	32	10	0	18	16	20	28	68	32	40	47	36	39	16	24	20	36	31
14	24	47	42	45	44	46	54	37	38	28	42	28	18	0	19	26	32	72	40	44	51	48	53	28	36	38	48	45
15	22	41	35	36	34	39	48	31	32	22	36	18	16	19	0	7	13	53	21	25	32	31	38	14	21	33	33	30
16	17	34	28	29	27	32	41	24	25	15	29	18	20	26	7	0	8	48	16	20	27	26	31	7	14	31	26	23
17	25	33	25	26	24	29	40	23	22	14	28	26	28	32	13	8	0	40	8	12	19	18	25	15	11	34	23	20
18	65	73	65	66	64	69	80	63	62	54	68	66	68	72	53	48	40	0	48	52	59	58	65	55	51	74	63	60
19	26	25	17	18	16	21	33	22	14	18	26	32	32	40	21	16	8	48	0	11	18	10	17	16	8	38	18	12
20	37	35	28	29	27	32	44	33	25	26	37	38	40	44	25	20	12	52	11	0	7	21	28	27	19	46	29	23
21	44	43	35	36	34	39	51	40	32	33	44	45	47	51	32	27	19	59	18	7	0	28	35	34	26	53	36	30
22	30	20	12	13	11	16	28	17	14	24	21	36	36	48	31	26	18	58	10	21	28	0	7	20	12	37	10	7
23	35	21	13	14	12	17	29	18	15	25	22	37	39	53	38	31	25	65	17	28	35	7	0	25	17	38	8	8
24	10	30	22	23	21	26	38	25	18	16	30	16	16	28	14	7	15	55	16	27	34	20	25	0	8	24	20	17
25	18	22	14	15	13	18	30	19	12	12	23	24	24	36	21	14	11	51	8	19	26	12	17	8	0	32	12	9
26	14	24	25	28	27	27	22	20	25	20	18	15	20	38	33	31	34	74	38	46	53	37	38	24	32	0	35	30
27	30	15	12	11	8	12	24	15	14	24	18	36	36	48	33	26	23	63	18	29	36	10	8	20	12	35	0	7
28	27	13	5	6	4	9	21	10	7	17	14	29	31	45	30	23	20	60	12	23	30	7	8	17	9	30	7	0

TABLE 6.2 (a)

DISTANCE MATRIX																												
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	0	999	999	999	999	999	999	999	22	18	999	6	6	999	999	999	999	999	999	999	999	999	999	10	999	14	999	999
2	999	0	8	7	10	6	8	10	999	999	8	999	999	999	999	999	999	999	999	999	999	999	999	999	24	16	13	
3	999	8	0	4	4	5	999	5	999	999	12	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	
4	999	7	4	0	3	4	999	8	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	11	6
5	999	10	4	3	0	9	999	7	999	999	10	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	8	4
6	999	5	5	4	9	0	999	5	999	999	9	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	12	9
7	999	8	999	999	999	999	0	999	999	999	12	999	999	999	999	999	999	999	999	999	999	999	999	999	999	22	32	999
8	999	10	5	8	7	9	999	0	10	9	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	20	999	10
9	22	999	999	999	999	999	999	10	0	10	999	22	24	999	999	999	999	999	14	999	999	16	999	18	12	25	999	7
10	18	999	999	999	999	999	999	9	10	0	14	18	18	28	26	15	14	999	18	999	999	999	999	16	12	20	999	999
11	999	8	12	999	10	9	12	999	999	14	0	999	999	999	999	999	999	999	999	999	999	999	999	999	999	18	20	16
12	6	999	999	999	999	999	999	999	22	18	999	0	10	999	18	18	999	999	999	999	999	999	999	18	999	15	999	999
13	6	999	999	999	999	999	999	999	24	18	999	10	0	18	16	20	999	999	999	999	999	999	999	20	999	999	999	999
14	999	999	999	999	999	999	999	999	999	28	999	999	18	0	19	28	999	999	999	999	999	999	999	28	999	999	999	999
15	999	999	999	999	999	999	999	999	999	26	999	18	16	19	0	7	13	999	999	999	999	999	999	14	999	999	999	999
16	999	999	999	999	999	999	999	999	999	15	999	18	20	28	7	0	8	999	999	999	999	999	999	7	14	999	999	999
17	999	999	999	999	999	999	999	999	999	14	999	999	999	999	13	8	0	40	8	12	999	999	999	999	11	999	999	999
18	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	40	0	999	999	999	999	999	999	999	999	999	999
19	999	999	999	999	999	999	999	999	14	18	999	999	999	999	999	999	8	999	0	11	999	10	999	8	999	18	12	
20	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	12	999	11	0	7	999	999	999	999	999	999	999
21	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	7	0	999	999	999	999	999	999	999
22	999	999	999	999	999	999	999	999	16	999	999	999	999	999	999	999	999	999	10	999	999	0	7	999	12	999	10	7
23	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	999	7	0	999	999	8	8	
24	10	999	999	999	999	999	999	999	18	16	999	18	20	28	14	7	999	999	999	999	999	999	999	0	8	999	999	999
25	999	999	999	999	999	999	999	999	12	12	999	999	999	999	999	14	11	999	8	999	999	12	999	8	0	999	12	9
26	14	24	999	999	999	999	22	20	25	20	18	15	999	999	999	999	999	999	999	999	999	999	999	999	999	0	999	999
27	999	16	999	11	8	12	32	999	999	999	20	999	999	999	999	999	999	999	18	999	999	10	8	999	12	999	0	7
28	999	13	5	6	4	9	999	10	7	999	16	999	999	999	999	999	999	999	12	999	999	7	8	999	9	999	7	0

NOTE- D(I,J) MEANS SHORTEST DIRECT LINK BETWEEN I AND J NODE
 D(I,J)=999 MEANS NO DIRECT LINK BETWEEN I AND J NODE

6.3.2 Demand at each delivery point: Demands at zonal delivery points are the input data to the model. Demand at any zonal delivery point is the summation of the demands of all delivery points grouped in that zone. Therefore, the demand at each delivery point is found first. Demand at any delivery point is the quantity indented by the agent at that delivery point. This quantity indented by the agent can be obtained from the indent book available with Sales Office of the Milk Board. Company is distributing milk twice-a-day (both in the morning and in the evening). Therefore, the morning and evening demand data at each delivery point have been collected first. With these data, the average morning and evening demand at each delivery point is calculated for each month. Indent book was available from January, 1974 only. So, because of non-availability of enough demand data, no forecasting model could be tried for estimation of demands. However, it was observed that morning and evening demand at each delivery point were not significantly varying for January, February and March months. Therefore, the average morning and evening demand for these three months were found. These average demands at delivery points have been called as Winter morning and evening demands. Similarly, the average morning and evening demands in months April, May and June have been found and have been called Summer morning and evening demands at delivery points. These average demands of all the delivery points in each zone are summed up to give average morning and evening demand (for summer and winter separately) at that zonal delivery point. Table 6.3 indicates the average demands at zonal delivery points.

6.3.3 Operating Characteristics of Vehicles

As was mentioned in Chapter 3, all vehicles are in same condition. So operating characteristics depend upon the size of vehicle and not on the condition of the vehicle. For each vehicle, the average travelling speed and maximum allowable load i.e. capacity is noted. These data have been tabulated in Table 6.5.

TABLE 6.3

DEMAND DATA (KANPUR SAHAKARI MILK BOARD)

NODE	SUMMER		WINTER	
	MORNING	EVENING	MORNING	EVENING
1	0	0	0	0
2	720	475	610	360
3	650	435	550	320
4	750	500	620	390
5	770	500	650	400
6	930	660	680	510
7	1100	640	930	640
8	1040	620	920	620
9	1150	710	930	600
10	500	335	340	160
11	740	580	620	380
12	920	620	810	510
13	670	425	550	310
14	820	580	730	480
15	600	435	500	300
16	760	510	650	380
17	1400	1165	1300	1000
18	800	810	500	280
19	1500	1070	1250	800
20	870	560	710	480
21	670	460	650	400
22	960	620	810	530
23	1040	680	870	600
24	1030	700	890	550
25	1140	760	1020	670
26	870	550	750	450
27	1200	760	1040	700
28	700	650	650	400

TABLE 6.4

VEHICLE CAPACITIES

Number of available vehicles = 9

<u>Vehicle number</u>	<u>Capacity</u> (bottles) *
1	4000
2	4000
3	1600
4	4000
5	1600
6	4000
7	4000
8	4000
9	4000

*Each bottle of half litre capacity.

TABLE 6.5

OPERATING CHARACTERISTICS OF VEHICLES AND DISTRIBUTION COSTS INVOLVED

- i) Average stop-off-time at each individual agent = 3.5 minutes
- ii) Average stop-off-time at depot = 120 minutes
- iii) Maximum Permissible route time = 300 minutes
- iv) Maximum Permissible Vehicle time = 420 minutes
- v) Average fuel consumption of diesel for vehicles with capacity of 4000 bottles = 4 km. per litre
- vi) Average fuel consumption of petrol for for small vehicles = 5 km/litre.
- vii) Average speed of bigger vehicles (capacity 4000 bottles) in morning = 20 k.m. per hour
- viii) Average speed of bigger vehicles in evening = 15 km. per hour
- ix) Average speed of smaller vehicles (capacity 1600 bottles) in morning = 25 km. per hour
- x) Average speed of smaller vehicles in evening = 20 km. per hour
- xi) Maintenance cost per vehicle per shift = Rs. 167 per month
- xii) Depreciation cost* for bigger vehicle = Rs. 277 per month
- xiii) Depreciation cost* for smaller vehicle = Rs. 84 per month
- xiv) Salaries
 - Drivers salary = Rs. 250/- r.m.
 - Route clerk's salary = Rs. 275/- p.m.
 - Helper's Salary = Rs. 210/- p.m.
 - Total Labour cost = Rs. 945/- p.m.
- xv) Cost of petrol = Rs. 3.27 per litre
Cost of diesel = Rs. 1.00 per litre

* Annual depreciation cost is 10% of initial purchase cost.

6.3.4 Distribution costs involved: Average consumption of fuel for each vehicle has been found. Knowing it, cost of fuel per kilometer for each vehicle has been found. Labour Cost includes Salary of driver, helpers and route clerk. These data have been taken from the accounts office of the milk board. Maintenance and depreciation costs for each vehicle on monthly average basis have been taken for each vehicle from the transport section of the milk board. Table 6.5 shows the different costs involved in distribution.

6.3.5 * Stop off-time at milk depot and delivery points: Estimates of stop-off-time* at the depot and the delivery points have been obtained from the dispatching section, Kanpur Sahakari Milk Board. Stop-off-time at a zonal delivery point, which is required as input data to Model, has been taken as summation of average stop-off-time at all the delivery points in that zone. Table 6.6 shows the stop-off-times at the zonal delivery points.

* average stop-off-time

TABLE 6.6

NUMBER OF AGENTS AND STOP-OFF-TIME AT THE NODES

NODE	NO. OF AGENTS	NO. OF AGENTS (ACTUALLY SERVED)		STOP OFF TIME (MINUTES)	
		MORNING	EVENING	MORNING	EVENING
1	0	0	0	120	120
2	9	9	6	31	21
3	10	10	6	35	21
4	9	9	5	31	17
5	8	7	4	25	14
6	10	9	6	31	21
7	10	10	6	28	21
8	9	9	5	31	17
9	9	9	5	31	17
10	10	10	7	35	25
11	9	9	6	31	21
12	8	8	6	28	21
13	10	10	7	35	25
14	9	9	4	31	14
15	10	10	8	35	28
16	8	8	7	28	25
17	9	9	9	31	31
18	10	10	4	35	14
19	10	9	7	31	25
20	10	10	7	35	25
21	8	8	5	28	17
22	10	10	6	35	21
23	10	10	7	35	25
24	10	10	7	35	25
25	9	9	5	31	17
26	11	11	7	38	25
27	7	7	6	25	21
28	9	9	8	31	28

CHAPTER-VII

RESULTS & DISCUSSION

In this chapter, the results obtained for the distribution system of the Kanpur Sahakari Milk Board have been presented and discussed. The distribution policies obtained using the model have been compared with the distribution policies presently adopted by the management of the Kanpur Sahakari Milk Board. A sensitivity analysis has been conducted for observing the sensitivity of results to the various parameters. Recommendations for the further work are given at the end of this Chapter.

7.1 Results for the distribution system of the Kanpur Sahakari Milk Board. The proposed distribution routes and vehicle dispatching strategies for the Kanpur Sahakari Milk Board presented in this section. The best possible results obtained by the proposed model, for the morning and evening shifts of the summer and winter months, are represented in tables 7.1 and 7.2, respectively. Table 7.1 indicates that the proposed vehicles, for the distribution in morning shift of summer months, are the vehicle numbers 1,2,3,4, 6,7,8*. This table also indicates the route path for each route and the vehicle allocation to the routes. Utilized capacities of vehicles (UVC) are given in column 4. The time (RT) for which vehicles are on the routes and the time for which each vehicle is engaged for distribution is indicated in column 5. The cost of transportation and the total cost, corresponding to the proposed routes and vehicle dispatching strategies for morning shift of summer months, are Rs. 1,239.77. per month and Rs. 10,768.77 per month respectively, as indicated by the table 7.1.(a)

The results for the morning and evening shifts of winter months are tabulated in table 7.2 which indicates the route path for the routes obtained and allocation of the selected vehicles to the routes. Costs of transportation for morning and evening shift are Rs. 1,407.10 per month and Rs. 1,168/- per month respectively. Total distribution costs are Rs. 9,547.10 per month and Rs. 7,725/- per month respectively, as indicated by table 7.2(a) and 7.2 (b).

*The available vehicles have been numbered as indicated in table 6.4

FCF SUMMER-MORNING DEMANDS

Route	Vehicle Number	Allocation Capacity (bottles)	Unused capacity (UVC)	Route time (RT) Mints.	Vehicle Time (VT) Mints.	Route Path
1	3	1600	10	76	196	1-13-12-1
2	1	4000	270	188	308	1-8-2-7-26-1
3	2	4000	100	185	305	1-27-23-22-28-1
4	4	4000	160	255	375	1-18-21-20-19-1
5	6	4000	180	181	301	1-25-9-10-24-1
6	7	4000	160	216	336	1-11-6-4-5-3-1
7	8	4000	420	185	305	1-14-15-17-16-1

Cost of transportation = Rs. 1,239.77 per month

Total cost of distribution = Rs. 10,768.77 per month

TABLE 7.1(b)
FOR SUMMER-EVENING DEMANDS

Route	Vehicle-allocation		Unused capacity	Route time	Vehicle time (RT)	Route path
	Number	Capacity (bottles)	(UVC)	(RT) Mints.	Mints.	
1	3	1600	140	69	189	1-25-24-1
2	1	4000	120	259	379	1-19-20-21-22-11-26-1
3	2	4000	75	293	413	1-16-17-18-15-14-13-1
4	4	4000	335	233	353	1-7-2-6-4-3-8-10-1
5	6	4000	80	215	335	1-27-23-5-28-9-12-1

Cost of transportation = Rs. 1,107.00 per month.

Total cost of distribution = Rs. 7,858.00 per month.

TABLE 7.2(a)

FOR WINTER-MORNING DEMANDS

Route	Vehicle-allocation Number	Capacity (bottles)	Unused Capacity (UVC)	Route time (RT) Mints.	Vehicle Time (VT) Mints.	Route Path
1	1	4000	200	258	378	1-4-6-2-7-11-10-1
2	2	4000	140	228	348	1-26-3-5-23-27-
3	4	4000	250	180	300	1-13-9-19-25-1
4	6	4000	190	283	403	1-21-20-18-17-16-1
5	3	1600	140	105	225	1-28-22-1
6	7	4000	150	245	365	1-24-15-14-8-12-1

Cost of transportation = Rs. 1,407.10 per month

Total cost of distribution = Rs. 9,547.10 per month

TABLE 7.2(b)

FOR WINTER-EVENING DEMANDS

Route	Vehicle-allocation		Unused capacity	Route time	Vehicle time	Route Path
	Number	Capacity (bottles)	(UVC)	(RT) Mints.	(VT) Mints.	
1	3	1600	60	207	327	1-18-20-21-16-1
2	5	1600	50	94	214	1-17-24-1
3	1	4000	330	263	383	1-9-25-19-15-14-13-12-1
4	2	4000	780	251	371	1-28-5-2-6-4-3-8-10-1
5	4	4000	700	245	365	1-26-7-11-27-23-22-1

Cost of transportation = Rs. 1,168.00 per month

Total cost of distribution = Rs. 7,725.00 per month

dispatching policies with that of the currently used policies of Kanpur Sahakari Milk Board: The proposed distribution routes and the vehicle dispatching strategies for the Kanpur Sahakari Milk Board have been discussed in Section 7.1 and are tabulated in Tables 7.1 and 7.2. The current distribution costs for the existing distribution system of Kanpur Sahakari Milk Board, are given in table 7.3. Table 7.4 shows the comparison of the distribution cost by the proposed vehicle policies with that of the currently used policies of Kanpur Sahakari Milk Board. The savings in total distribution cost obtained by the use of proposed model, are indicated in last column of Table 7.4. For the morning shift of summer months, the saving of 24% has been observed. For the evening shift of summer months, the saving has been observed to the tune of 21% .

For the morning and evening shifts of winter months, the savings in total distribution costs have been observed more than that for summer months. The reason for the higher savings in winter months can be explained as follows: The number of vehicles (obtained by proposed model) employed for satisfying customers' demands in winter months, are less than that employed in summer months, because of less demand in winter months. On the other hand, the number of vehicles employed for the distribution, by the management, Kanpur Sahakari Milk Board, are same for both winter and summer months. For the morning shift of winter months, the saving obtained by proposed solution is 32.6%. For the evening shift of winter months, the saving observed is 22.8%. In general, the savings obtained by the proposed distribution policies over the currently used policies by Kanpur Sahakari Milk Board are to the tune of 20 to 32%.

7.3 Effect of various vehicle-set-selection policies and vehicle-allocation policies : In this section, the effect of various vehicle-set selection policies and vehicle allocation policies on the objective function has been discussed. To study the effect of various policies on the objective function, the problem has been solved with various policies

TABLE 7.3

DISTRIBUTION COSTS FOR EXISTING DISTRIBUTION SYSTEM OF KANPUR SAHAKARI MILK BOARD

(Estimates given by Management, Kanpur Sahakari Milk Board)

i) For morning shift

Cost of transportation = Rs. 2,100.00 per month

Maintenance, labour and depreciation cost = Rs. 12,113.00 per month

Total cost = Rs. 14,213.00 per month.

ii) For evening shift

Cost of transportation = Rs. 1,797.00 per month.

Maintenance, labour and depreciation cost = Rs. 8,140.00 per month

Total cost of distribution = Rs. 9,937.00 per month

TABLE 7.4

COMPARISON OF THE TOTAL DISTRIBUTION COST BY PROPOSED DISPATCHING POLICIES WITH THAT OF THE CURRENTLY USED POLICIES OF KANPUR SAHAKARI MILK BOARD

	Total cost of distribution (Rs/month)		Savings %
	Existing System	Proposed System	
Summer-morning	14213.00	10768.77	24.0%
Summer-evening	9937.70	7858.00	21.2%
Winter-morning	14213.00	9547.10	32.6%
Winter-evening	9937.70	7725.00	22.8%

for the different sets of demands. Different sets of demands have been obtained by varying the original demands at each customer from -20% to +20% in step of 5%. For each demand set, the total costs of distribution for different vehicle set-selection-policies and vehicle-allocation policies have been indicated in Table 7.5. These results indicate that different combinations of vehicle-set-selection policies and vehicle-allocation policies yield different costs of distribution.

7.3.1 Effect of Vehicle-set-selection policies

Vehicle-set-selection policy selects the set of vehicles for distribution to satisfy the customers' demands. In this section, the effect of different vehicle-set-selection policies on the cost of distribution has been discussed. Fig. 1 shows the maintenance, depreciation and labour costs for different vehicle-set-selection policies with variation in summer-morning demands of each customer from -20% to +20% in step of 5%. Fig. 1 shows that vehicle-set-selection policy 2, in general, gives higher cost, exceptional cases being only when demand at each node increases by 5% or reduces by 10%. Use of vehicle-set-selection policy 2 results in higher cost because in this policy, the available vehicles are arranged in ascending order of their capacities and smaller capacity vehicles are selected first. Therefore for satisfying the customer demands, vehicle-set-selection policy 2 requires more number of vehicles than required by vehicle-set-selection policy 1 in which vehicles are arranged in descending order of the capacities. When demand increases by 5%, the reason for lower cost by using policy 2 than that by using policy 3, is that policy 2 selects 2 small and 6 big capacity vehicles whereas the policy 3 selects 1 small and 7 big capacity vehicles. The number of vehicles in both cases are same but higher depreciation cost, in case of big capacity vehicles, causes policy 3 to yield higher cost.

In Fig. 2 a graphical relationship between the total cost of distribution and the various demand sets considering different vehicle-set-selection policies is presented. Fig. 2 shows that in all the cases, vehicle-set selection policy 2 gives higher cost. When demand is varied by

TABLE 7.5

TOTAL COST OF DISTRIBUTION (RS./MONTH) FOR DIFFERENT SETS OF DEMANDS, USING VARIOUS
SET SELECTION POLICIES AND VEHICLE ALLOCATION POLICIES

(Different sets of demands have been obtained by varying the summer-morning demands
in step of $\pm 5\%$)

Per- centage Varia- tion	Total demands (bottles/ day)	TOTAL COST OF DISTRIBUTION (RS./MONTH)											
		Vehicle-set-selection Policy 1			Vehicle-set-Selection Policy 2			Vehicle-set-Selection Policy 3			Vehicle-allocation Policies		
		Vehicle-allocation policies			Vehicle-allocation policies			Vehicle-allocation policies			Vehicle-allocation Policies		
		I	II	III	I	II	III	I	II	III	I	II	III
-20	19440	9815	9815	9815	10904	10894	10920	9540	9592	9732	9540	9592	9732
-15	20655	9755	9755	9755	10998	11018	11251	9550	9321	9435	9550	9321	9435
-10	21870	9509	9509	9509	11031	10901	10991	10712	10709	10796	10712	10709	10796
-5	23085	9524	9524	9524	12209	12100	12290	10865	10752	10710	10865	10752	10710
0	24300	10990	10990	10990	12117	12154	12307	10914	10873	10768	10914	10873	10768
5	25515	11183	11183	11183	12283	12318	12398	12181	12095	12219	12181	12095	12219
10	26730	11098	11098	11098	13480	13310	13430	12410	12501	12198	12410	12501	12198
15	27945	12398	12410	12480	13570	13400	13510	12218	12248	12338	12218	12248	12338
20	29000	12518	12472	12540	13498	13512	13408	12518	12472	12540	12518	12472	12540

Cost of maintenance, depreciation and labour cost (Rs./Month), for different sets of demands, using various set policies. (Different sets of demands have been obtained by varying the summer-morning-demands in Step of $\pm 5\%$)

Percentage Variation	Total demands (bottles/day)	Cost of maintenance, depreciation & labour cost			(Rs./month)
		Vehicle-set-selection Policy 1	Vehicle-set-selection Policy 2	Vehicle-set-selection Policy 3	
-20	19440	8334	9335	8140	
-15	20655	8334	9335	8140	
-10	21870	8334	9335	9529	
-5	23085	8334	10724	9529	
0	24300	9723	10724	9529	
5	25515	9723	10724	10918	
10	26730	9723	12113	10918	
15	27945	10918	12113	10918	
20	29100	10918	12113	10918	

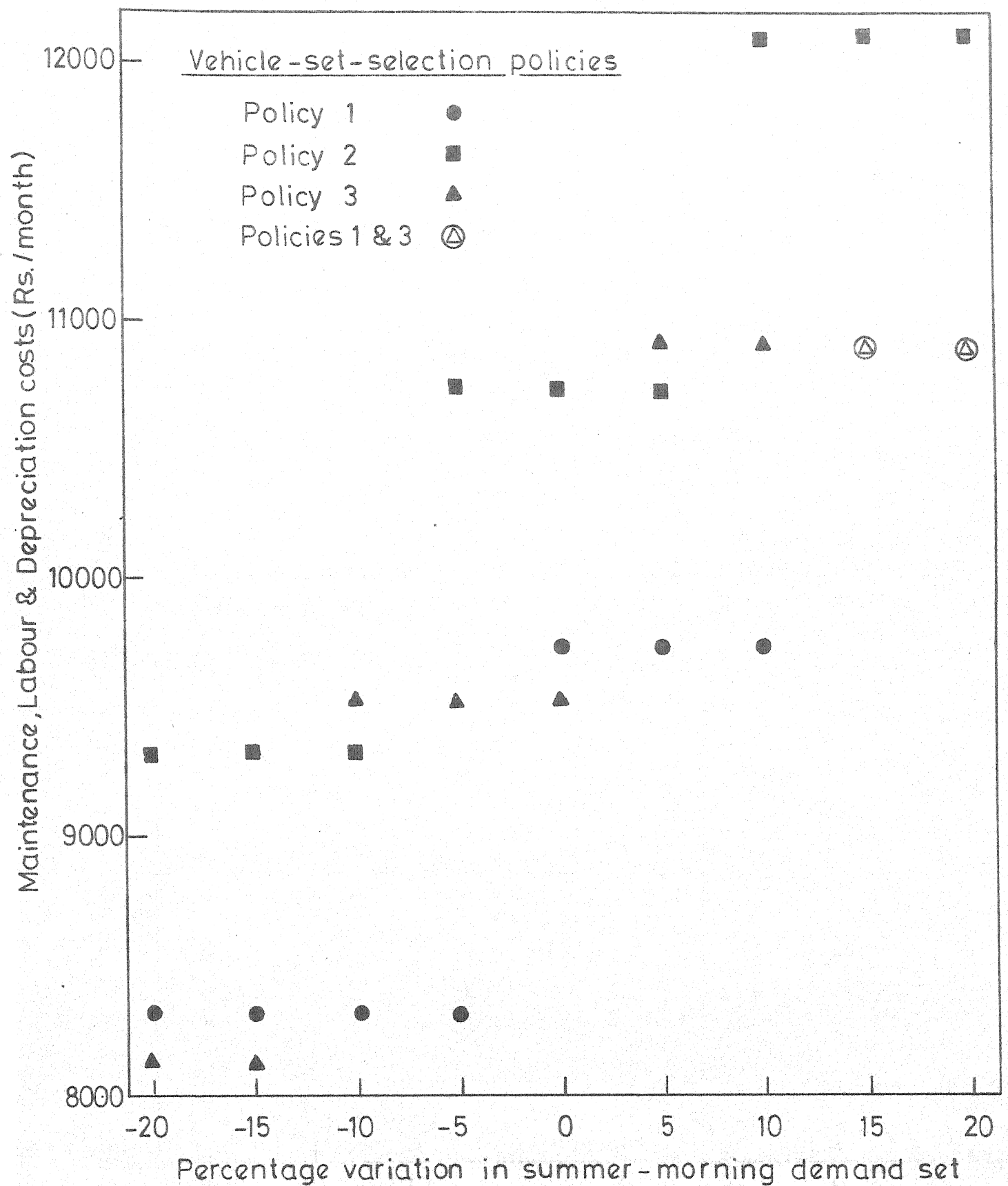


Fig. 1 - Effect of various Vehicle-Set-Selection Policies on the Maintenance, Labour and Depreciation cost, for the different sets of Demands.

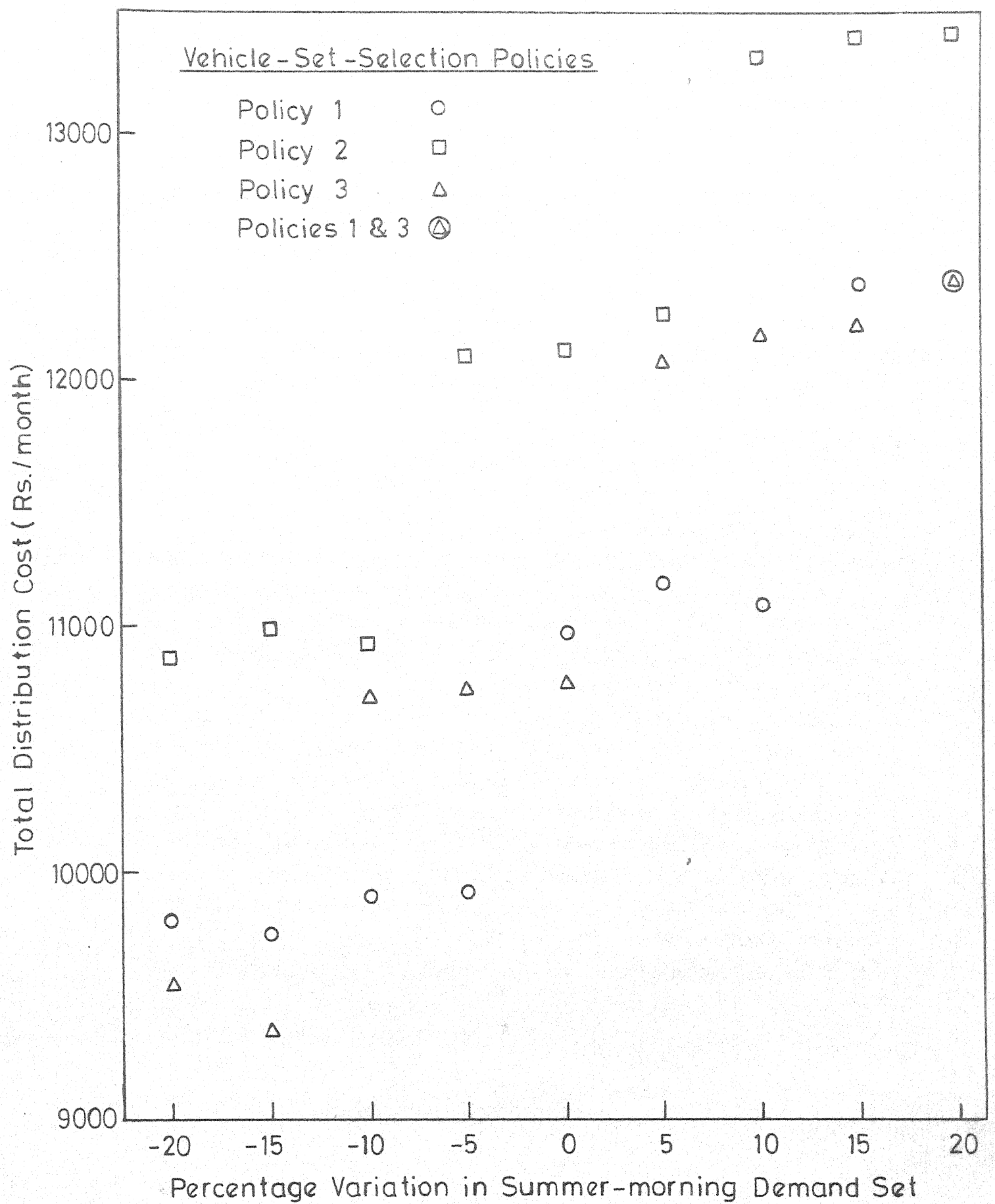


Fig. 2 - Effect of Various Vehicle -Set-Selection Policies on the Total Distribution cost, for the different sets of Demands.

5%, though the maintenance, labour and depreciation costs are observed to be lower in case of policy 2 than in case of policy 3 (Fig. 1), the total distribution cost is observed to be higher with use of policy 2 (as indicated by Fig.2). This is due to the fact that the vehicle-set-selection policy 2 selects more number of small vehicles which use petrol (big vehicles use diesel). Petrol being more expensive than diesel, the cost of transportation is more with use of vehicle-set-selection policy 2. Therefore, one can conclude that the vehicle-set-selection policy 2 for selecting the vehicles is uneconomical. However, as the results show (Fig. 2) there is nothing much to choose between policies 1 & 3. On the other hand, policy 3 being that of random selection, it is recommended that policy 1 be used for implementation.

7.3.2 Effect of Vehicle-allocation policies

Vehicle-allocation policy allocates the vehicles (selected by vehicle-set-selection policies) to the initial routes and then routes are adjusted, accordingly, for the capacity of vehicle allocated to it. Figs. 3 through 5 show the effect of various vehicle allocation policies on the total distribution cost with variation in demand for the particular vehicle-set-selection policy. When the vehicles selected by a vehicle-set-selection policy, are of the same capacities, every vehicle allocation policy gives the same results as indicated by Fig. 3. This is because the vehicle allocation to the initial routes is the same in every case. However, the various policies yield different results when vehicles of different capacities are employed. No conclusion could be drawn about the superiority of one vehicle allocation policy over the other. Results show (Fig. 3) that there is nothing much to choose between vehicle-allocation policies 1, 2 and 3. Fig. 6 shows the relationship between cost of transportation and demand with use of various vehicle allocation policies.

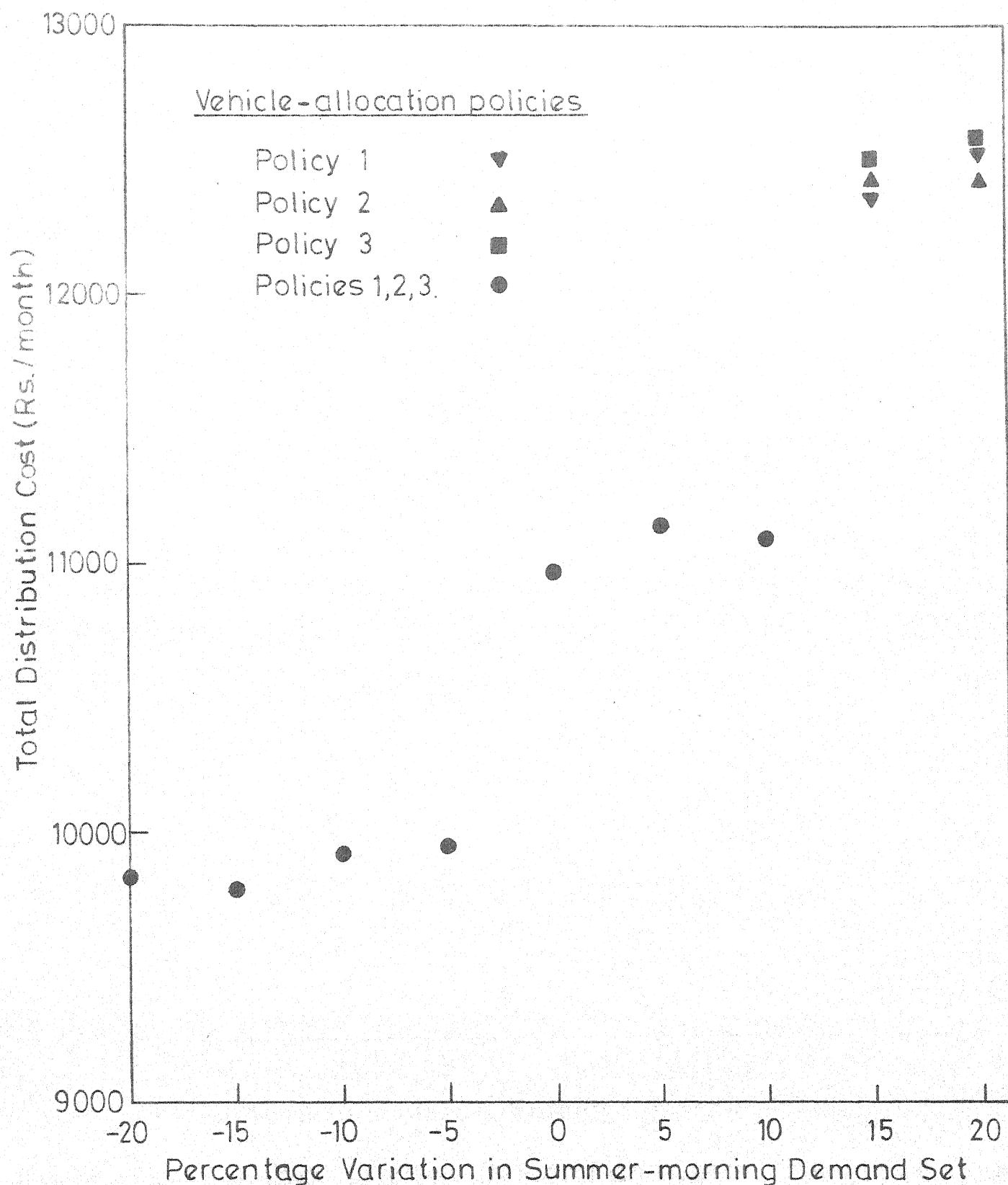


Fig. 3 - Relationship between the Demand and Total Distribution Cost, with use of different Vehicle-allocation Policies and considering Vehicle-Set-Selection Policy 1.

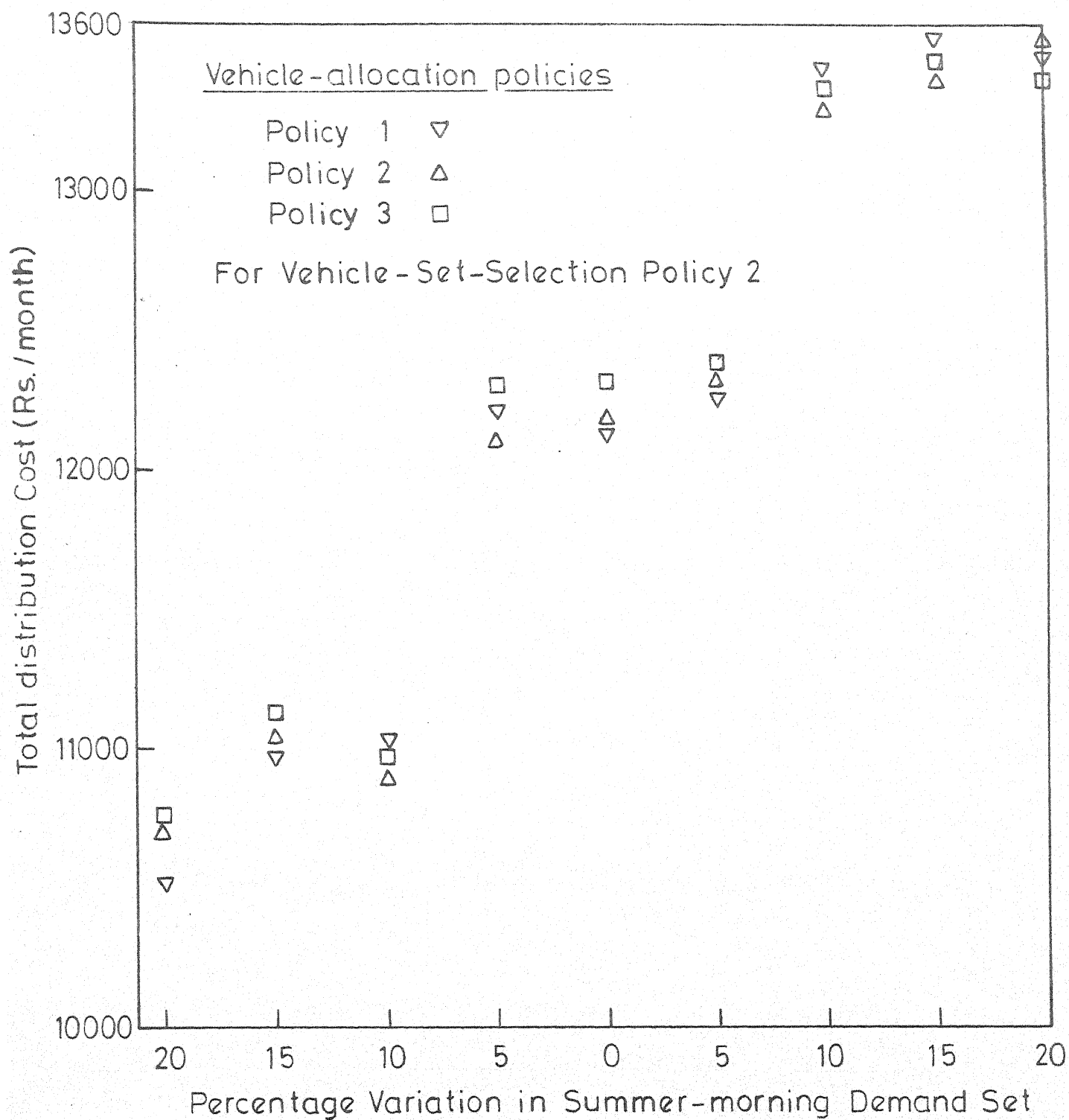


Fig. 4 - Relationship between Demand and Total Distribution Cost, with use of different Vehicle-Allocation Policies and considering Vehicle-Set-Selection Policy 2.

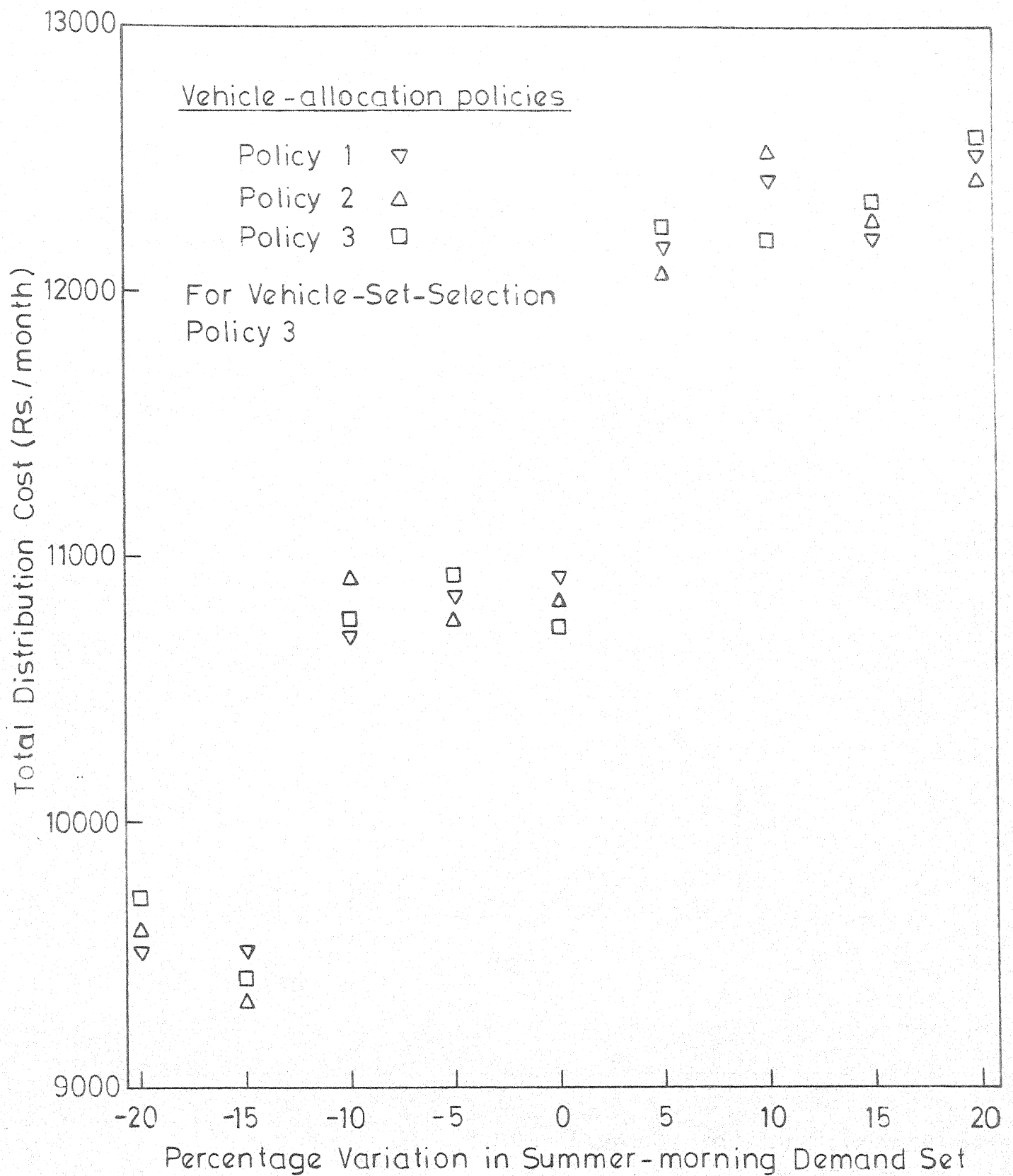


Fig. 5 -Relationship between the Demand and the Total Distribution Cost with use of different Vehicle-Allocation Policies and Considering Vehicle-Set-Selection Policy 2.

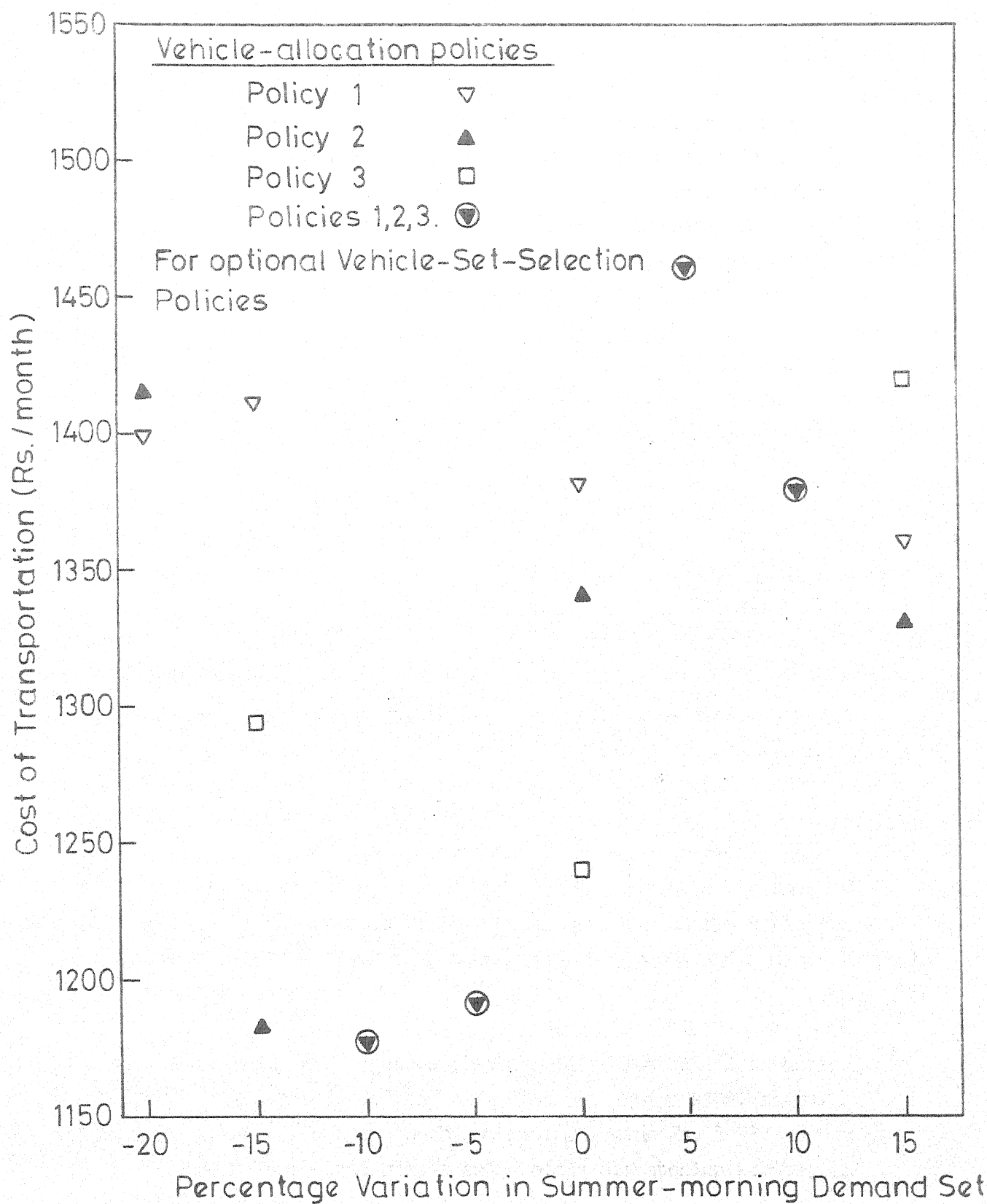


Fig. 6 -Relationship between the Demand and the Cost of Transportation with use of various Vehicle-Allocation Policies.

7.4 Sensitivity Analysis

It consists of changing the values of parameters either one at a time or simultaneously. Here-in, changes have been made only one at a time. Among the various parameters, the parameter subjected to sensitive analysis, in present work, is 'demand' parameter for observing its effect on the objective function. This is due to the fact that demand varies frequently, depending upon the customers' requirement. Table 7.7 and Fig. 7 show the effect of variation in Winter-Morning demand set on the optimal cost of transportation and optimal total distribution cost obtained by the proposed method. It is observed that the total cost of distribution for demand variation of -20% to -6% does not change significantly, maximum being Rs. 8173/- per month and minimum being Rs. 7983/- per month. Similarly, no significant variation in total distribution cost for the present demand set, is observed till the demand at each customer increases by 12%, maximum being Rs. 9547/- p.m. and minimum being Rs. 9494/- p.m.. Because of practical difficulties involved in frequent change of the vehicle dispatching strategies with the change in customers' demand, it is recommended that upto 12% increase in demand at each customer, same vehicle routes and vehicle dispatching strategies are followed, because of no significant change in the optimal cost of distribution. Because of capacity constraints of vehicles, the routes for distribution in practice should be those obtained for maximum demand at each customer i.e., for the demands increased by 12% at each customer. Table 7.8 shows the routes and vehicles allocated to them which can be used for satisfying the customers' demands anywhere between present demands and demands increased by 12% at each customer.

Similarly, Fig. 7 shows that the total cost of distribution, for demand variation between -20% and -6%, does not change significantly, maximum being Rs. 8173/- per month and minimum being Rs. 7983/- per month. Table 7.9 shows the optimal routes and vehicle dispatching strategies

EFFECT OF VARIATION IN WINTER-MORNING DEMAND SET ON
OPTIMAL COST OF TRANSPORTATION AND TOTAL COST OF
DISTRIBUTION

<u>Percentage</u> <u>variation</u>	<u>Cost of Transportation</u> <u>Rs./month</u>	<u>Total cost of distribution</u> <u>(Rs./month)</u>
-20%	1422.70	8173.70
-15%	1095.50	8040.50
-10%	1038.80	7983.80
-7%	1113.75	8058.75
-6%	1103.60	8048.60
-5%	1303.70	8443.70
0%	1407.00	9547.00
5%	1162.35	9496.35
10%	1184.62	9518.62
12%	1150.20	9494.20
15%	1246.20	10775.20
20%	1368.90	10897.90

Table 7.8

Recommended routes and vehicle-dispatching strategies for the variation of demands at each customer between -20% and -6% of present winter-morning demand set.

<u>Route</u>	<u>Vehicle-allocation</u>		<u>Route path</u>
	<u>Number</u>	<u>Capacity</u>	
1	1	4000	1-15-16-18-21-20-19-1
2	2	4000	1-12-8-17-24-1
3	4	4000	1-10-9-22-23-27-1
4	6	4000	1-26-7-2-4-5-28-1
5	7	4000	1-25-3-6-11-14-13-1

Total cost of distribution = Rs. 8043.6 per month

Table 7.9

Recommended routes and vehicle-dispatching strategies for the variation of demands at each customer upto +12% of present winter-morning demand set

<u>Route</u>	<u>Vehicle-allocation</u>		<u>Route path</u>
	<u>Number</u>	<u>Capacity</u>	
1	1	4000	1-9-3-4-6-11-1
2	2	4000	1-28-22-23-27-1
3	4	4000	1-10-8-2-7-26-1
4	6	4000	1-21-20-18-17-1
5	7	4000	1-25-5-19-16-1
6	8	4000	1-24-15-14-13-12-1

Total cost of distribution = Rs. 9494.2 per month

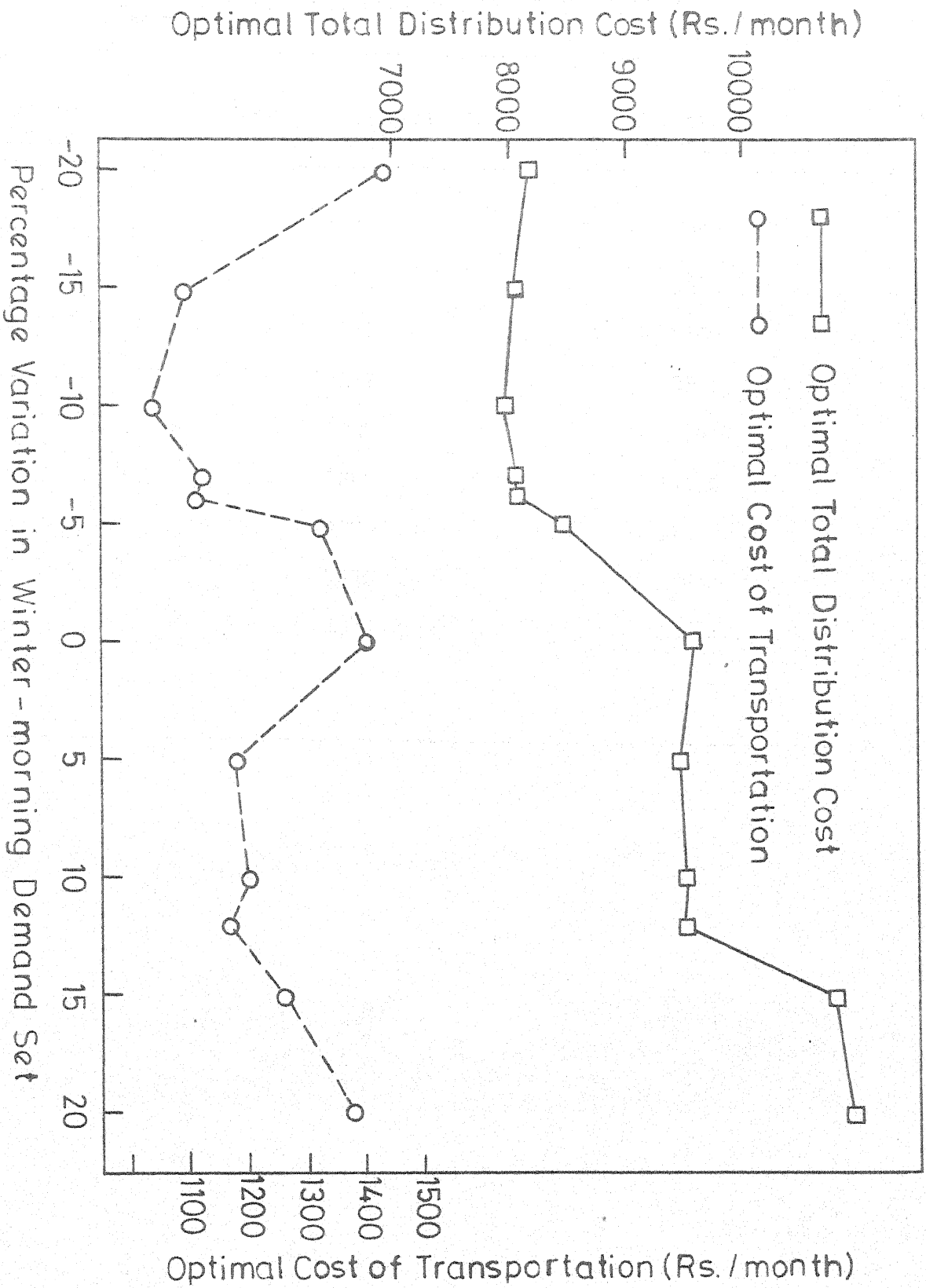


Fig. 7 - Effect of Variation in Winter-morning Demand on Optimal Cost of Transportation and Optimal Distribution Cost.

TABLE 7.10

EFFECT OF VARIATION IN SUMMER-MORNING DEMAND SET ON
OPTIMAL COST OF TRANSPORTATION AND TOTAL COST OF
DISTRIBUTION

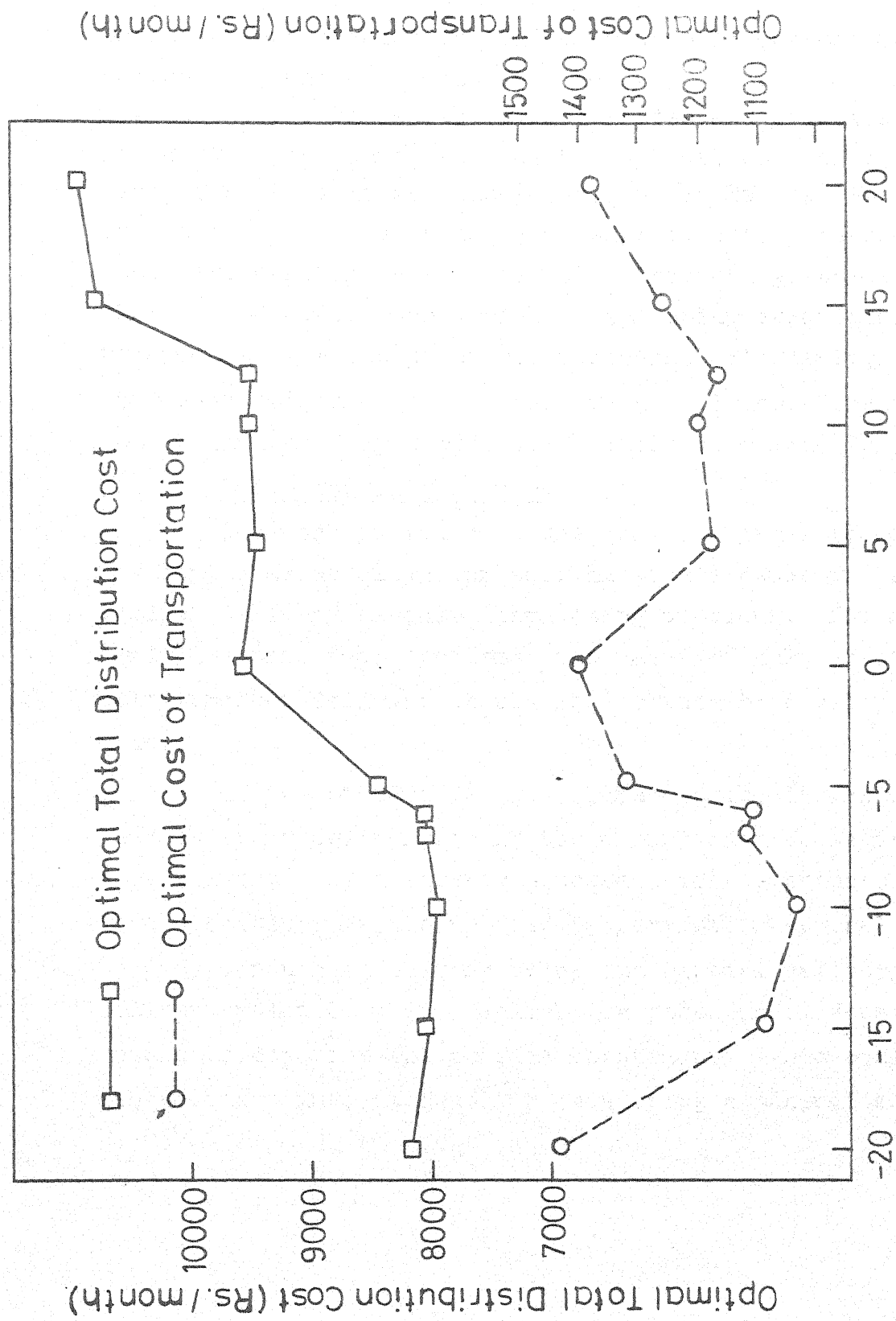
Percentage Variation	Cost of transportation (Rs./month)	Total cost of distribution (Rs./month)
-20%	1122	9262
-15%	1161	9321
-10%	1172	9506
-5%	1182	9516
0%	1239	10768
5%	1294	11016
10%	1320	11043
15%	1330	12248
20%	1360	12472

Table 7.11

Recommended routes and vehicle-dispatching strategies for the variation of demands at each customer upto +10% of present summer-morning demand set

<u>Route</u>	<u>Vehicle-allocation</u>		<u>Route path</u>
	<u>No.</u>	<u>Capacity</u>	
1	1	4000	1-5-27-25-1
2	2	4000	1-2-7-11-24-1
3	4	4000	1-10-17-18-16-1
4	6	4000	1-21-20-15-14-13-1
5	7	4000	1-9-28-3-26-1
6	8	4000	1-23-22-19-1
7	9	4000	1-4-6-8-12-1

Total cost of distribution = Rs. 11043.30 per month



Percentage Variation in Winter-morning Demand Set

Fig. 7 - Effect of Variation in Winter-morning Demand on Optimal Cost of Transportation and Optimal Distribution Cost.

which are recommended for the variation in demands at each customer anywhere between -6% and -20%. Total cost of distribution, for these recommended routes and policies, is Rs. 8048/- per month, whereas the optimal cost of distribution, for the demands reduced by 10%, is Rs. 7983/- per month. But this difference is not very significant. Therefore, to avoid frequent changes in vehicle dispatching strategies with change in demand, such vehicle dispatching strategies are recommended for the practical purposes. Similarly, the results have been obtained for the variation in Summer-Morning demand set as indicated by Tables 7.10, Table 7.11 and Fig. 8.

7.5 Scope for further work

The work outlined in the previous pages attempts at developing methodology for solving single depot and single product delivery vehicle dispatching problems. For more real life practical problems, the cases of multi-depot and multi-product delivery should be included to develop a general model.

In the problem, as formulated above, it was assumed that at every delivery point the demand must be satisfied by one delivery. As a further extension of the proposed model, this condition, may be relaxed by permitting several routes to pass through a delivery point and partial delivery at the delivery point by the vehicles. Proposed model does not take into consideration the traffic constraint. This constraint may be taken into account for developing a generalized model.

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*
APPENDIX

*
* COMPUTER LISTING *
*

*
* DETERMINATION OF OPTIMAL ROUTES AND VEHICLE *
* DISPATCHING STRATEGIES FOR A DISTRIBUTION NETWORK *
*

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*****
*   PROGRAM 1 FOR CONSTRUCTING INITIAL ROUTES   *
*****
DIMENSION KDD(40,40),MINSEQ(20,40),Z(50),NEQ(20),LINSEQ(20,40)
DIMENSION ID(40,40),MMTP(40),LEQ(20),IES(20),LIN(50),LES(20)
DIMENSION SPTS(40),SPPS(40),DD(40,40),JCB1(40),JCB2(40)
DIMENSION KINSEQ(20,40),KKEQ(20)
DIMENSION KDSD(32,32)
INTEGER Z,ZZ,ZLB,ZUB,DD,SPTS,SPPS
COMMON/SLM/MINSEQ, KK
COMMON/RNC/LINSEQ, KDD, N
COMMON/VSS/DD
COMMON/NEEN/NV
READ 6083, A
6083 FORMAT(F5.1)
490 READ 1, NC
1  FORMAT(I3)
   IF(NC.EQ.100) GO TO 9000
   NCC=NC+1
   A=A+5.0
   PRINT 6053, NC
6053 FORMAT(1H1, //10X, *NO. OF CUSTOMERS =*, I4/)
   PRINT 6054
6054 FORMAT(//20X, *DISTANCE MATRIX*//)
   PRINT 6055, ((I), I=1, NCC)
6055 FORMAT(3X, 32I4)
   DO 101 I=1, NC
   JJ=I+1
   READ 102, (KDSD(I, II), II=JJ, NCC)
101  CONTINUE
102  FORMAT(20I4)
   DO 103 I=1, NCC
   DO 103 J=1, NCC
   IF(J.GT.I) GO TO 103
   IF(J.EQ.I) GO TO 104
   KDSD(I, J)=KDSD(J, I)
   GO TO 103
104  KDSD(I, J)=9999
103  CONTINUE
   DO 6020 I=1, NCC
   PRINT 6030, I, (KDSD(I, J), J=1, NCC)
6020 CONTINUE
6030 FORMAT(I3, 1X, 32I4)
6000 READ 2, NV
2  FORMAT(I3)
   IF(NV.EQ.500) GO TO 490
   PRINT 6007, NC, NV
6007 FORMAT(1H1, ///9X, *NO. OF CUSTOMERS =*, I3/9X, *NO. OF VEHICLE =*, I3/)
   NVV=NV+1
   N=NV+NC
   DO 6070 I=1, NV
   DO 6070 J=1, N
   IF(J.GT.NV) GO TO 6080
   KDD(I, J)=9999
   GO TO 6070
6080 JJ=J-NV+1
   KDD(I, J)=KDSD(I, JJ)
6070 CONTINUE
   PRINT 5050

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5050 FORMAT(/10X,*INITIAL ROUTES BY MULTIPLE TRAVELLING SALESMEN PRO*)PRO0024
      DO 6090 I=NV,N
      II=I-NV+1
      DO 6090 J=1,N
      IF(J.GT.NV)GO TO 6095
      KDD(I,J)=KDSD(II,1)
      GO TO 6090
6095 JJ=J-NV+1
      KDD(I,J)=KDSD(II,JJ)
6090 CONTINUE
      IF(NV.EQ.2)GO TO 6081
      GO TO 6088
6081 PRINT 740,((I),I=1,N)
740  FORMAT(/15X,*AUGMENTED DISTANCE MATRIX*,//4X,40(I3))
      DO 730 I=1,N
      PRINT 720,I,(KDD(I,J),J=1,N)
730  CONTINUE
720  FORMAT(I3,2X,40I3)
6088 DO 5 I=1,N
      DO 5 J=1,N
      DD(I,J)=KDD(I,J)
      5  CONTINUE
      CALL ASGNM(MINSEQ,ZZ,KN,NEQ,N)
      IF(KN.EQ.1000)GO TO 9008
      PRINT 710
710  FORMAT(/15X,*INITIAL ASSIGNMENT GIVES FOLLOWING SUBTOURS*,/)
      PRINT 6079
6079 FORMAT(/1X,*SUBTOUR*,2X,*PATH SEQUENCE*,/)
      DO 7 I=1,KN
      KPS=NEQ(I)
      PRINT 8,I,(MINSEQ(I,J),J=1,KPS)
      8  FORMAT(1X,I3,5X,41(I3))
      7  CONTINUE
      PRINT 9,ZZ
      9  FORMAT(/10X,*INITIAL LOWER BOUND=*,I5)
      CALL FEAS(MINSEQ,NEQ,KN,IES,KK)
      IF(KK.EQ.0)GO TO 500
C*****FINDING INITIAL UPPER BOUND
      KNZ=0
      DO 10 I=1,KN
      KPSP=NEQ(I)
      DO 11 J=1,KPSP
      LINSEQ(I,J)=MINSEQ(I,J)
      11 CONTINUE
      LEQ(I)=KPSP
      10 CONTINUE
      LL=KK
      DO 12 I=1,KK
      LES(I)=IES(I)
      12 CONTINUE
      KMN=KN
      CALL UPRBND(KZUB,LEQ,LES,LL,KMN)
      ZUB=KZUB
      PRINT 810,ZUB
810  FORMAT(/10X,*BELOW TOURS BY INITIAL HEURISTICS*,10X,*U.B.=*I5/)
      DO 811 I=1,KMN
      JOIT=LEQ(I)
      PRINT 812,(LINSEQ(I,J),J=1,JOIT)
812  FORMAT(5X,41(I3))

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811  CONTINUE
    IF(ZUB.EQ.ZZ)GO TO 600
    GO TO 650
500  PRINT 13
    13  FORMAT(//5X,*ABOVE TOURS ARE FINAL AND MIN DIS IS INITIAL L.B.*)
    GO TO 6000
600  PRINT 16
    16  FORMAT(//10X,*FINAL TOURS ARE AS OBTAINED BY INITIAL HEURISTICS*)
    GO TO 6000
650  DO 663 I=1,N
    DO 663 J=1,N
    IC(I,J)=KDD(I,J)
663  CONTINUE
    700 CALL SHORT(IES,NEQ,MMTP,LMS,LIN)
    LNS=LMS-1
    MM=0
    DO 120 I=1,LNS
    II=I+1
    MM=MM+1
    SPTS(MM)=MMTP(I)
    SPPS(MM)=MMTP(II)
120  CONTINUE
    KONT=0
    DO 130 JHUM=1,MM
    DO 131 I=1,N
    DO 131 J=1,N
    DD(I,J)=ID(I,J)
131  CONTINUE
    KTE1=SPTS(JHUM)
    KTE2=SPPS(JHUM)
    DD(KTE1,KTE2)=9999
    CALL ASGNM(MINSEQ,ZZ,KN,NEQ,N)
    IF(KN.EQ.1000)GO TO 9008
    IF(ZZ.GE.ZUB)GO TO 135
    KONT=KONT+1
    Z(KONT)=ZZ
    JOB1(KONT)=KTE1
    JOB2(KONT)=KTE2
    CALL FEAS(MINSEQ,NEQ,KN,IES,KK)
    IF(KK.EQ.0)GO TO 140
    GO TO 130
140  ZUB=ZZ
    KNZ=KN
    DO 7054 I=1,KNZ
7054  KKEQ(I)=NEQ(I)
    DO 141 I=1,KNZ
    KPSE=KKEQ(I)
    DO 746 J=1,KPSE
    KINSEQ(I,J)=MINSEQ(I,J)
746  CONTINUE
142  FORMAT(1X,I3,5X,4I13)
141  CONTINUE
    GO TO 130
135  CONTINUE
130  CONTINUE
    IF(KONT.EQ.0)GO TO 2000
    CALL MIN(Z,KONT,KENT,MKONT)
    ZLB=MKONT
    IF(ZLB.EQ.ZUB)GO TO 2000

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PRO0082

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PRO014

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KTE3=JOB1(KENT)
KTE4=JOB2(KENT)
DO 695 I=1,N
DO 695 J=1,N
DD(I,J)=ID(I,J)
695 CONTINUE
DD(KTE3,KTE4)=9999
CALL ASGNM(MINSEQ,ZZ,KN,NEQ,N)
IF(KN.EQ.1000)GO TO 9008
DO 691 I=1,N
DO 691 J=1,N
ID(I,J)=DD(I,J)
691 CONTINUE
CALL FEAS(MINSEQ,NEQ,KN,IES,KK)
IF(KK.EQ.0)GO TO 3000
GO TO 700
3000 PRINT 3003,ZZ
3003 FORMAT(/10X,*FINAL TOURS ARE AS FOLLOWS*,5X,*ZZ=*,I5)
PRINT 6079
DO 3001 I=1,KN
KPZS=NEQ(I)
PRINT 3002,I,(MINSEQ(I,J),J=1,KPZS)
3002 FORMAT(1X,I3,5X,41(I3))
3001 CONTINUE
GO TO 6000
2000 IF(KNZ.EQ.0)GO TO 7808
PRINT 2001,ZUB
2001 FORMAT(/20X,*FOLLOWING TOURS ARE OPTIMAL*,10X,*MIN DIS =*,I5)
PRINT 6079
DO 2050 I=1,KNZ
KPSE=KKEQ(I)
PRINT 2060,I,(KINSEQ(I,J),J=1,KPSE)
2060 FORMAT(1X,I3,5X,41(I3))
2050 CONTINUE
GO TO 6000
7808 PRINT 16
GO TO 6000
9008 PRINT 9007
9007 FORMAT(/1X,*MISTAKE IN FINDING MIN.LIN.REQD.CHECK SUBR.*)
GO TO 6000
9000 STOP
END

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ISN

SOURCE STATEMENT

0		\$IBFTC FEAS	PR
1		SJBROUTINE FEAS(NINSEQ,KEQ,KLN,KES,MK)	PR
2		COMMON/NEEN/NV	PR
3		DIMENSION NINSEQ(20,40),KEQ(20),KES(20)	PR
4		MK=0	PR
5		DO 5 I=1,KLN	PR
6		KPS=KEQ(I)	PR
7		DO 6 J=1,KPS	PR
10		KTT=NINSEQ(I,J)	PR
11		DO 7 JJ=1,NV	PR
12		IF(KTT.EQ.JJ)GO TO 5	PR
15	7	CONTINUE	PR
17	6	CONTINUE	PR
21		MK=MK+1	PR
22		KES(MK)=I	PR
23	5	CONTINUE	PR
25		RETURN	PR
26		END	PR

NO MESSAGES FOR ABOVE ASSEMBLY

FORTTRAN SOURCE LIST

FORTTRAN SOURCE LIST

[illegible]

IBMAP ASSEMBLY SHORT

NO MESSAGES FOR ABOVE ASSEMBLY

ISN SOURCE STATEMENT

0	\$IBFTC	JPRBND	PRI
1		SUBROUTINE UPRBND(KZUB,LEQ,LES,LL,KMN)	PRI
2		COMMON/RUM/IP	PRI
3		DIMENSION LINSEQ(20,40),KDD(40,40),LEQ(20),LES(20),IP(40,40)	PRI
4		DIMENSION IFEAS(20),INFEAS(20)	PRI
5		COMMON/RNC/LINSEQ,KDD,N	PRI
6		DO 1 I=1,N	PRI
7		DO 1 J=1,N	PRI
10		IP(I,J)=0	PRI
11	1	CONTINUE	PRI
14		CALL PMATRIX(KMN,LEQ)	PRI
15	100	L=0	PRI
16		K=0	PRI
17		DO 2 I=1,KMN	PRI
20		DO 3 J=1,LL	PRI
21		IF(I.EQ.LES(J))GO TO 4	PRI
24	3	CONTINUE	PRI
26		K=K+1	PRI
27		IFEAS(K)=I	PRI
30		GO TO 2	PRI
31	4	L=L+1	PRI
32		INFEAS(L)=I	PRI
33	2	CONTINUE	PRI
35		CALL SEARCH(L,K,INFEAS,IFEAS,LEQ,N1,N2,N3,N4,IFFST,IEERT)	PRI
36		IP(N1,N3)=1	PRI
37		IP(N1,N2)=2	PRI
40		IP(N4,N2)=1	PRI
41		IP(N4,N3)=2	PRI
42		CALL MNSQ(IP,KDD,N,LINSEQ,LEQ,KMN,IZUB)	PRI
43		CALL FEAS(LINSEQ,LEQ,KMN,LES,LL)	PRI
44		IF(LL.EQ.0)GO TO 1005	PRI
47		GO TO 100	PRI
50	1005	KZUB=IZUB	PRI
51		RETURN	PRI
52		END	PRI

MEG250

IBMAP ASSEMBLY UPRBND

NO MESSAGES FOR ABOVE ASSEMBLY

ISBN

SOURCE STATEMENT

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0 $1BFTC SEARCH
1  SUBROUTINE SEARCH(L,K,INFEAS,IFEAS,NEQ,N1,N2,N3,N4,IFFST,IERT)
2  COMMON/RNC/LINSEQ,KCD,N
3  DIMENSION LINSEQ(20,40),KDD(40,40),INFEAS(20),IFEAS(20),NEQ(20)
4  DIMENSION IXP(40),KIXP(40),IPX(40),KIPX(40),IFST(20),IERT(20)
5  DIMENSION IIPX(40),KKIPX(40),I1(20),I2(20),I3(20),I4(20)
6  DIMENSION NDIS(50),MINDIS(50),MINMUM(50),IFRT(20),MININC(20)
7  DIMENSION J1(20),J2(20),J3(20),J4(20)
10 KZ=0
11 DO 3 I=1,L
12   IM=INFEAS(I)
13   KPS=NEQ(IM)
14   KW=0
15   DO 4 J=1,K
16     IN=IFEAS(J)
17     KPN=NEQ(IN)
20     KRN=KPN-1
21     KV=0
22     DO 5 JJ=1,KRN
23       KV=KV+1
24       KTT=LINSEQ(IN,JJ)
25       JK=JJ+1
26       KTM=LINSEQ(IN,JK)
27       IXP(KV)=KTT
30       KIXP(KV)=KTM
31       KQ=0
32       DO 6 II=2,KPS
33         KTS=LINSEQ(IM,II)
34         IK=II-1
35         KTN=LINSEQ(IM,IK)
36         IDIS=KDD(KTT,KTS)
37         JDIS=KDD(KTN,KTM)
40         KDIS=KDD(KTN,KTS)
41         KQ=KQ+1
42         NDIS(KQ)=IDIS+JDIS-KDIS
43         IPX(KQ)=KTS
44         KIPX(KQ)=KTN
45   5 CONTINUE
47   CALL MIN(NDIS,KQ,KQQ,MET)
50   IIPX(KV)=IPX(KQQ)
51   KKIPX(KV)=KIPX(KQQ)
52   MDIS=KDD(KTT,KTM)
53   MINDIS(KV)=MET-MDIS
54   5 CONTINUE
56   CALL MIN(MINDIS,KV,KVV,MER)
57   KW=KW+1
60   MINMUM(KW)=MER
61   I1(KW)=IXP(KVV)
62   I2(KW)=KIXP(KVV)
63   I3(KW)=IIPX(KVV)
64   I4(KW)=KKIPX(KVV)
65   IFRT(KW)=IN
66   4 CONTINUE
70   CALL MIN(MINMUM,KW,KWW,MEP)
71   KZ=KZ+1

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EG250

FORTTRAN SOURCE LIST SEARCH

ISN	SOURCE STATEMENT	
72	MININC(KZ)=MEP	PR
73	J1(KZ)=I1(KWW)	PR
74	J2(KZ)=I2(KWW)	PR
75	J3(KZ)=I3(KWW)	PR
76	J4(KZ)=I4(KWW)	PR
77	IFST(KZ)=IFRT(KWW)	PR
100	IERT(KZ)=IM	PR
101 3	CONTINUE	PR
103	CALL MIN(MININC,KZ,KZZ,MEM)	PR
104	MINI=MEM	PR
105	N1=J1(KZZ)	PR
106	N2=J2(KZZ)	PR
107	N3=J3(KZZ)	PR
110	N4=J4(KZZ)	PR
111	IFFST=IFST(KZZ)	PR
112	IEERT=IERT(KZZ)	PR
113	RETURN	PR
114	END	PR

EG250

IBMAP ASSEMBLY SEARCH

NO MESSAGES FOR ABOVE ASSEMBLY

ISN

SOURCE STATEMENT

0	\$IBFTC	ASGNM	PR
1		SUBROUTINE ASGNM(MANS,Q,IZ,KN,NEQ,N)	PR
2		INTEGER DD,P,UNMRKR,UC,UR,UZ,D	PR
3		COMMON/VSS/DD	PR
4		COMMON/JLM/P	PR
5		COMMON/ZLM/D	PR
6		DIMENSION DD(40,40),P(40,40),UNMRKR(40),MRRKC(50)	PR
7		DIMENSION D(40,40),IPOK(40),ISOK(40),NDIS(100),IXP(100),IPX(100)	PR
10		DIMENSION MANSEQ(20,40),NEQ(20)	PR
11		DO 710 I=1,N	PR
12		DO 710 J=1,N	PR
13		D(I,J)=DD(I,J)	PR
14	710	CONTINUE	PR
17	160	CALL ZERO(N)	PR
20		DO 107 I=1,N	PR
21		DO 107 J=1,N	PR
22		P(I,J)=0	PR
23	107	CONTINUE	PR
26		CALL ASSIGN(N,IPOK,ISOK,KOK)	PR
27	995	INDEX=0	PR
30		DO 123 I=1,N	PR
31		DO 123 J=1,N	PR
32		IF(P(I,J).EQ.1)INDEX=INDEX+1	PR
35	123	CONTINUE	PR
40		IF(INDEX.EQ.N)GO TO 110	PR
43		CALL MINLIN(UNMRKR,UR,MRRKC,UC,N)	PR
44		UZ=UR+UC	PR
45		IF(INDEX.EQ.UZ)GO TO 150	PR
50		IF(INDEX.GT.UZ)GO TO 118	PR
53		GO TO 141	PR
54	113	PRINT 119	PR
55	119	FORMAT(/10X,*SOMETHING WRONG IN FINDING MIN. LINES REQD.*)	PR
56		GO TO 5000	PR
57	141	IF(UZ.LT.N)GO TO 150	PR
62		GO TO 166	PR
63	150	CALL CRZERO(N,UNMRKR,MRRKC,UR,UC)	PR
64		GO TO 160	PR
65	110	CALL MNSQ(P,DD,N,MANSEQ,NEQ,KN,IZ)	PR
66		GO TO 500	PR
67	166	DO 920 I=1,N	PR
70		KAKI=0	PR
71		DO 921 J=1,N	PR
72		IF(P(I,J).EQ.1)GO TO 920	PR
75	921	CONTINUE	PR
77		DO 922 K=1,N	PR
100		DIS=DD(I,K)	PR
101		DO 923 KK=1,N	PR
102		IF(F(KK,K).EQ.1)GO TO 924	PR
105	923	CONTINUE	PR
107		GO TO 925	PR
110	924	DO 950 J=1,N	PR
111		IF(F(KK,J).EQ.1)GO TO 950	PR
114		DO 990 JPS=1,N	PR
115		IF(P(JPS,J).EQ.1)GO TO 950	PR
120	990	CONTINUE	PR

FORTRAN SOURCE LIST ASGNM

[illegible]

IBMAP ASSEMBLY ASGNM

NO MESSAGES FOR ABOVE ASSEMBLY

[illegible][illegible]

IBMAP ASSEMBLY ZERO

NO MESSAGES FOR ABOVE ASSEMBLY

ISN

SOURCE STATEMENT

```
0 $IBFTC ASSIGN
1 SUBROUTINE ASSIGN(N,IPOK,ISOK,KOK)
2 COMMON/JLM/P
3 COMMON/ZLM/D
4 INTEGER D,P
5 DIMENSION D(40,40),P(40,40),LCOUNT(50),IPOK(40),ISOK(40)
6 KJK=0
7 LK=0
10 INDEX=1
11 990 NJM=0
12 MJM=0
13 DO 1 I=1,N
14 DO 201 J=1,N
15 LCOUNT(J)=0
16 201 CONTINUE
20 DO 11 K=1,N
21 IF(D(I,K).EQ.0)GO TO 6
24 GO TO 11
25 6 IF(P(I,K).EQ.0)NUM=NUM+1
30 11 CONTINUE
32 IF(NUM.LE.INDEX)GO TO 3
35 GO TO 1
36 3 DO 2 J=1,N
37 IF(D(I,J).EQ.0)GO TO 4
42 LCOUNT(J)=10*N
43 GO TO 2
44 4 IF(P(I,J).EQ.0)GO TO 501
47 LCOUNT(J)=10*N
50 GO TO 2
51 501 DO 102 IMC=1,N
52 IF(D(IMC,J).NE.0)GO TO 102
55 IF(P(IMC,J).NE.0)GO TO 102
60 LCOUNT(J)=LCOUNT(J)+1
61 102 CONTINUE
63 2 CONTINUE
65 CALL MIN(LCOUNT,N,J1,MINX)
66 IF(MINX.EQ.10*N)GO TO 1
71 P(I,J1)=1
72 KJK=KOK+1
73 IPOK(KOK)=I
74 ISOK(KOK)=J1
75 DO 5 II=1,N
76 IF(II.EQ.1)GO TO 5
101 P(II,J1)=2
102 5 CONTINUE
104 DO 8 JJ=1,N
105 IF(JJ.EQ.J1)GO TO 8
110 P(I,JJ)=2
111 8 CONTINUE
113 1 CONTINUE
115 DO 301 J=1,N
116 DO 302 I=1,N
117 LCOUNT(I)=0
120 302 CONTINUE
122 DO 303 K=1,N
```

ISN	SOURCE STATEMENT
123	IF(D(K,J).EQ.0)GO TO 304
126	GO TO 303
127 304	IF(P(K,J).EQ.0)MUM=MUM+1
132 303	CONTINUE
134	IF(MUM.LE.INDEX)GO TO 305
137	GO TO 301
140 305	DO 306 I=1,N
141	IF(D(I,J).EQ.0)GO TO 307
144	LCOUNT(I)=10*N
145	GO TO 306
146 307	IF(P(I,J).EQ.0)GO TO 308
151	LCOUNT(I)=10*N
152	GO TO 306
153 308	DO 309 JMC=1,N
154	IF(D(I,JMC).NE.0)GO TO 309
157	IF(P(I,JMC).NE.0)GO TO 309
162	LCOUNT(I)=LCOUNT(I)+1
163 309	CONTINUE
165 305	CONTINUE
167	CALL MIN(LCOUNT,N,I1,NIMX)
170	IF(NIMX.EQ.10*N)GO TO 301
173	P(I1,J)=1
174	KJK=KOK+1
175	IPOK(KOK)=I1
176	ISOK(KOK)=J
177	DO 310 IK=1,N
200	IF(IK.EQ.I1)GO TO 310
203	P(IK,J)=2
204 310	CONTINUE
206	DO 311 JK=1,N
207	IF(JK.EQ.J)GO TO 311
212	P(I1,JK)=2
213 311	CONTINUE
215 301	CONTINUE
217	LP=0
220	DO 900 I=1,N
221	DO 900 J=1,N
222	IF(P(I,J).EQ.1)LP=LP+1
225 900	CONTINUE
230	IF(LP.EQ.LK)GO TO 901
233	LK=LP
234	GO TO 980
235 901	INDEX=INDEX+1
236 980	JJJ=0
237	DO 960 I=1,N
240	DO 960 J=1,N
241	IF(D(I,J).EQ.0)GO TO 970
244	GO TO 960
245 970	IF(P(I,J).EQ.0)JJJ=JJJ+1
250 960	CONTINUE
253	IF(JJJ.EQ.0)GO TO 999
256	GO TO 990
257 999	RETURN
260	END

ISN

SOURCE STATEMENT

```

0 $IBFTC MINLIN
1 SUBROUTINE MINLIN(UNMRKR,UR,MRRKC,UC,N)
2 CMMOV/ZLM/D
3 CMMOV/JLM/P
4 INTEGER D,P,UNMRKR,UC,UR
5 DIMENSION D(40,40),P(40,40),UNMRKR(40),MRKC(100),MRKR(100),MR(100)
6 DIMENSION MC(100),JP(100),NINA(100),MRRKC(50)
7 KM=0
10 KL=0
11 IR=0
12 IC=0
    C**** TJ MARK ROWS HAVING NO ASSIGNED ZERO
13 DJ 1 I=1,N
14 DJ 2 J=1,N
15 IF(P(I,J).EQ.1)GO TO 1
20 2 CONTINUE
22 KL=KL+1
23 MR(KL)=I
24 1 CONTINUE
26 DJ 101 I=1,KL
27 IR=IR+1
30 MRKR(IR)=MR(I)
31 101 CONTINUE
    C* '**** TJ MARK COLUMNS HAVING ZEROS IN ABOVE MARKED ROWS
33 DJ 3 I=1,N
34 DJ 4 J=1,KL
35 IF(I.EQ.MR(J))GO TO 5
40 4 CONTINUE
42 GO TO 3
43 5 DJ 6 J=1,N
44 IF(D(I,J).EQ.0)GO TO 7
47 GO TO 6
50 7 KM=KM+1
51 MC(KM)=J
52 IF(KM.EQ.1)GO TO 6
55 KM=KM-1
56 DJ 21 II=1,KN
57 IF(MC(KM).EQ.MC(II))GO TO 22
62 21 CONTINUE
64 GO TO 6
65 22 KMS=KM
66 MC(KMS)=0
67 KM=KM-1
70 6 CONTINUE
72 3 CONTINUE
74 DJ 102 I=1,KM
75 IC=IC+1
76 MRKC(IC)=MC(I)
77 102 CONTINUE
    C**** TJ MARK ROWS HAVING ASSIGNED ZEROS CORRESP TO ABOVE MARKED COL.
101 CALL STEP1(N,MC,KM,JP,KTT)
102 IF(KTT.EQ.0)GO TO 11
105 DJ 103 I=1,KTT
106 IR=IR+1
107 MRKR(IR)=JP(I)

```

ISN SOURCE STATEMENT

```
110 103 CONTINUE
C*****TO MARK COLUMNS HAVING ZEROS IN ABOVE MARKED LINES
112 200 CALL STEP2(N,JP,KTT,NINA,MODE)
113 IF(MODE.EQ.0)GO TO 11
116 ID=IC
117 IE=ID+1
120 DO 104 J=1,MODE
121 IC=IC+1
122 MRKC(IC)=NINA(J)
123 104 CONTINUE
125 DO 105 J=1,ID
126 DO 106 JJ=IE,IC
127 IF(MRKC(J).EQ.MRKC(JJ))GO TO 150
132 GO TO 106
133 150 JT=JJ-ID
134 NINA(JT)=0
135 MRKC(JJ)=0
136 106 CONTINUE
140 105 CONTINUE
142 CALL STEP1(N,NINA,MODE,JP,KTT)
143 IF(KTT.EQ.0)GO TO 11
146 IT=IR
147 IJ=IR+1
150 DO 107 I=1,KTT
151 IR=IR+1
152 MRKR(IR)=JP(I)
153 107 CONTINUE
155 DO 109 II=1,KTT
156 DO 108 I=1,IT
157 IF(MRKR(I).EQ.JP(II))GO TO 160
162 GO TO 108
163 160 IM=IT+II
164 MRKR(IM)=0
165 JP(II)=0
166 108 CONTINUE
170 109 CONTINUE
172 GO TO 200
173 11 UR=0
174 DO 301 I=1,N
175 DO 302 J=1,IR
176 IF(MRKR(J).EQ.I)GO TO 301
201 302 CONTINUE
203 UR=UR+1
204 UNMRKR(UR)=I
205 301 CONTINUE
207 UC=0
210 DO 303 J=1,N
211 DO 304 K=1,IC
212 IF(MRKC(K).EQ.J)GO TO 305
215 304 CONTINUE
217 GO TO 303
220 305 UC=UC+1
221 MRRKC(UC)=J
222 303 CONTINUE
224 RETURN
```

MEG250

ISN

SOURCE STATEMENT

FORTRAN SOURCE LIST MINLIN

225

END

MEG250

IBMAP ASSEMBLY MINLIN

NO MESSAGES FOR ABOVE ASSEMBLY

MLG250
ISN

SOURCE STATEMENT

FORTRAN SOURCE LIST

```
0 $IBFTC STEP1
1     SJBROUTINE STEP1(N,KR,KM,JP,KTT)
2     COMMON/JLM/P
3     COMMON/ZLM/D
4     INTEGER D,P
5     DIMENSION D(40,40),P(40,40),KR(100),JP(100)
6     KT=0
7     DO 9 J=1,N
10    DO 10 IK=1,KM
11    10 CONTINUE
13    GO TO 9
14    11 DO 12 I=1,N
15    IF(P(I,J).EQ.1)GO TO 13
20    12 CONTINUE
22    GO TO 9
23    13 KT=KT+1
24    JP(KT)=I
25    9 CONTINUE
27    KTT=KT
30    RETURN
31    END
```

MLG250

IBMAP ASSEMBLY STEP1

NO MESSAGES FOR ABOVE ASSEMBLY

ISN

SOURCE STATEMENT

```
0 $IBFTC STEP2
1     SJBROUTINE STEP2(N,JP,KTT,NINA,MODE)
2     COMMON/JLM/P
3     COMMON/ZLM/D
4     DIMENSION D(40,40),P(40,40),JP(100),NINA(100)
5     INTEGER D,P
6     KD=0
7     DO 14 I=1,N
10    DO 15 KT=1,KTT
11        IF(I.EQ.JP(KT))GO TO 16
14    15    CONTINUE
16        GO TO 14
17    16    DO 18 J=1,N
20        IF(D(I,J).EQ.0)GO TO 17
23        GO TO 18
24    17    IF(P(I,J).EQ.1)GO TO 18
27        KD=KD+1
30        NINA(KD)=J
31        IF(KD.EQ.1)GO TO 18
34        ML_A=KD-1
35        DO 30 II=1,ML_A
36        IF(NINA(KD).EQ.NINA(II))GO TO 31
41    30    CONTINUE
43        GO TO 18
44    31    ML_ZP=KD
45        NINA(ML_ZP)=0
46        KD=KD-1
47    18    CONTINUE
51    14    CONTINUE
53        MODE=KD
54        RETURN
55        END
```

MEG250

IBMAP ASSEMBLY STEP2

NO MESSAGES FOR ABOVE ASSEMBLY

ISN

SOURCE STATEMENT

```
0 $IBFTC CRZERO
1      SUBROUTINE CRZERO(N,UNMRKR,MRKC,UR,UC)
2      COMMON/ZLM/D
3      INTEGER D,UNMRKR,UC,UR
4      DIMENSION D(40,40),UNMRKR(40),MRKC(50),IB(40,40),JB(50),JBJ(50)
5      KM=0
6      DO 1 I=1,N
7      DO 2 K=1,UR
10     IF(UNMRKR(K).EQ.I)GO TO 1
13     2 CONTINUE
15     KM=KM+1
16     KL=0
17     DO 4 J=1,N
20     DO 5 L=1,UC
21     IF(MRKC(L).EQ.J)GO TO 4
24     5 CONTINUE
26     KL=KL+1
27     IB(KM,KL)=D(I,J)
30     4 CONTINUE
32     1 CONTINUE
34     DO 7 I=1,KM
35     DO 8 J=1,KL
36     JB(J)=IB(I,J)
37     8 CONTINUE
41     CALL MIN(JB,KL,KLN,MNL)
42     JBJ(I)=MNL
43     7 CONTINUE
45     CALL MIN(JBJ,KM,KMN,MNM)
46     DO 9 I=1,N
47     DO 10 K=1,UR
50     IF(UNMRKR(K).EQ.I)GO TO 11
53     10 CONTINUE
55     DO 12 J=1,N
56     DO 13 L=1,UC
57     IF(MRKC(L).EQ.J)GO TO 14
62     13 CONTINUE
64     IF(D(I,J).EQ.9999)GO TO 14
67     D(I,J)=D(I,J)-MNM
70     GO TO 12
71     14 D(I,J)=D(I,J)
72     12 CONTINUE
74     GO TO 9
75     11 DO 15 J=1,N
76     DO 21 L=1,UC
77     IF(MRKC(L).EQ.J)GO TO 16
102    21 CONTINUE
104    D(I,J)=D(I,J)
105    GO TO 15
106    16 IF(D(I,J).EQ.9999)GO TO 15
111    D(I,J)=D(I,J)+MNM
112    15 CONTINUE
114    9 CONTINUE
116    RETURN
117    END
```

MEG250

IBMAP ASSEMBLY CRZERO

NO MESSAGES FOR ABOVE ASSEMBLY

MEG250

FORTRAN SOURCE LIST

ISN

SOURCE STATEMENT

```
0  $IBFTC MIN
1      SJBROJTINE MIN(P,N,K,RMIN)
2      INTEGER P,RMIN,SUM
3      DIMENSION P(50)
4      K=1
5      SJM=P(1)
6      IF(N.EQ.1)GO TO 2
11     DO 1 I=2,N
12     IF(P(I).GE.SUM)GO TO 1
15     K=I
16     SJM=P(I)
17     1  CONTINUE
21     2  RMIN=SUM
22     RETURN
23     END
```

MEG250

IBMAP ASSEMBLY MIN

NO MESSAGES FOR ABOVE ASSEMBLY

MEG250

IBLDR -- JOB 000000

*** OBJECT PROGRAM IS BEING ENTERED INTO STORAGE AT 11 HRS. 22 MTS

```

*****
*
* PROGRAM FOR ADJUSTING INITIAL ROUTES FOR CAPACITY *
* AND TIME CONSTRAINTS AND FOR REFINING THE ADJUSTED*
* ROUTES. PROGRAM ALSO CONSIDERS OMITTED CUSTOMERS. *
*
*****
C*****THIS PROGRAM ADJUSTS THE INITIAL ROUTS TO BE WITHIN CAPACITY
C AND TIME CONSTRAINT FOR LEAST INCREASE IN DISTANCE
C AND THEN IMPROVES THE ROUTES BY REFINING HEURISTICS
C*** THIS PROGRAM IS APPLICABLE TO BOTH TYPE OF VEHICLES
C*****N(I) DENOTES NO. OF NODES(EXCLUDING DEPOT IN SUBTOUR I
C*****TOTAL NO. OF NODES ARE NC. OF CUSTOMERS PLUS NO. OF ARTIFICIAL
C DEPOTS WHICH ARE EQUAL TO NO. OF VEHICLES
C*****B(I,J) IS DISTANCE MATRIX SHOWING DISTANCES BETWEEN ALL NODES
C*****D(.) DENOTES DEMANDS OF ALL NODES.DEMANDS FOR ARTIFICIAL DEPOTS
C ARE ZERO, THAT MEANS D(1),D(2),D(3) ETC. ARE ZERO.
C*****KRT(I,J) DENOTES JTH CUSTOMER IN ITH ROUTE FOR EXAMPLE IN SUB-
C TOUR 1-4-6-5-1, KRT(1,1)=4,KRT(1,2)=6 ETC.
C*****INITIAL TOURS OBTAINED IS,SAY,IN THE FORM- 1-4-6-5-3-10-11-1 THEN
C SUBTOURS ARE 1-4-6-5-1 AND 3-10-11-3 PUT DATA IN THIS FORM
C IS EQUAL TO 1 THEN ROUTE TRAVERSES FROM I TO J NCDE
DIMENSION N(10),MMX(40,40),KRT(10,30),D(40),B(40,40)
DIMENSION JMX(40,40),OVC(10),UVC(10),KAPO(10),KEP(10),OOVC(10)
DIMENSION NBKJ(40,40),JDB(40)
DIMENSION KTOVC(10),C(10)
DIMENSION IMEK(10)
DIMENSION TCR(10),JRTD(10),JRT(10),JVT(10)
INTEGER B,C,T,D,OVC,UVC,COVC
DIMENSION JST(40),JAV(10),CT(10),FX(10),JSET(10),JAL(10),CST(10)
INTEGER TD
COMMON/OPM/B,T,JMX,KRT
COMMON/JLM/D,C
COMMON/STS/NV,NN
3081 FORMAT(2I3)
READ 3081,(JAV(I),I=1,2)
READ 3082,(CT(I),I=1,2)
3082 FORMAT(2F6.1)
READ 3083,(FX(I),I=1,2)
3083 FORMAT(2F8.1)
320 READ 101,NC
101 FORMAT(I3)
IF(NC.EQ.100)GO TO 7010
NCC=NC+1
DO 1580 I=1,NC
JJ=I+1
READ 1582,(NBKJ(I,II),II=JJ,NCC)
1580 CONTINUE
1582 FORMAT(20I4)
902 FORMAT(1H1,5X,*SET POLICY*,I3/10X,*SET NUMBER*,I3/10X,*VEHICLES TO
6 BE USED*,10I3)
903 FORMAT(/10X,*NO. OF CUSTOMERS =*,I3)
DO 103 I=1,NCC
DO 103 J=1,NCC
IF(J.GT.I)GO TO 103
IF(J.EQ.I)GO TO 1588
NBKJ(I,J)=NBKJ(J,I)
GO TO 103
1588 NBKJ(I,J)=9999

```

```

103  CONTINUE
    READ 1571,(JST(I),I=1,NCC)
1571  FORMAT(20I4)
    READ 340,(JDB(J),J=1,NCC)
340   FORMAT(20I4)
321   READ 7123,NPOLCY,MIPCY,CODE
7123  FORMAT(2I3,F6.1)
    IF(NPOLCY.EQ.100)GO TO 320
950   READ 910,NV
910   FORMAT(I3)
    IF(NV.EQ.500)GO TO 321
    READ 3088,(JSET(I),I=1,NV)
    NVV=NV+1
    NN=NV+NC
    DO 351 I=1,NV
    DO 351 J=1,NN
    IF(J.GT.NV)GO TO 356
    B(I,J)=9999
    GO TO 351
356   JJ=J-NV+1
    B(I,J)=NBKJ(I,JJ)
351   CONTINUE
    DO 352 I=NVV,NN
    II=I-NV+1
    DO 352 J=1,NN
    IF(J.GT.NV)GO TO 355
    B(I,J)=NBKJ(II,1)
    GO TO 352
355   JJ=J-NV+1
    B(I,J)=NBKJ(II,JJ)
352   CONTINUE
    DO 9100 I=1,NV
    OVC(I)=0
9100  UVC(I)=0
365   CONTINUE
367   DO 375 I=1,NN
    IF(I.LE.NV)GO TO 956
    II=I-NV+1
    D(I)=JDB(II)
    GO TO 375
956   D(I)=0
375   CONTINUE
377   CONTINUE
    RVP=BVP/100.
    DVP=RVP+1.0
    DO 7121 I=1,NN
    XLD=FLOAT(D(I))
7121  D(I)=IFIX(DVP*XLD)
    PRINT 7122,BVP,(D(I),I=1,NN)
7122  FORMAT(1H1,10X,*DEMANDS AT EACH NODE INCREASED BY*,F6.1,*PERCENT*,
6/5X,20I5/5X,20I5)
380   READ 102,(N(I),I=1,NV)
102   FORMAT(10I4)
397   FORMAT(/5X,*INITIAL TOURS BY MULTIPLE TRAVELLING SALESMEN PROB*/)
1592  FORMAT(/20X,*DEMANDS ARE AS FOLLOWS*/5X,20I5/5X,20I5)
393   FORMAT(/8X,*SUBTOUR*,5X,*NO. OF NODES*,5X,*PATH SEQUENCE*/)
    DO 105 I=1,NV
    NPL=N(I)
    READ 106,(KRT(I,J),J=1,NPL)

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```

105 CONTINUE
106 FORMAT(25I3)
391 FORMAT(10X,I3,10X,I3,10X,25I3)
C***** CODE=0. FOR CONSTANT CAPACITY VEHICLE
C CODE=1. FOR DIFFERENT SIZED VEHICLES
JPOLCY=0
8888 JPOLCY=JPOLCY+1
IF(CODE.EQ.0.)GO TO 9227
IF(JPOLCY.GT.3)GO TO 950
PRINT 902,NPOLCY,MIPCY,(JSET(I),I=1,NV)
PRINT 342,NV
399 FORMAT(5X,*CONSIDERING VEHICLE-POLICY*,I3)
GO TO 9228
9227 IF(JPOLCY.GT.1)GO TO 950
PRINT 902,NPOLCY,MIPCY,(JSET(I),I=1,NV)
PRINT 342,NV
9228 READ 100,T,(C(I),I=1,NV)
100 FORMAT(15I5)
READ 3085,(JAL(I),I=1,NV)
3085 FORMAT(10I3)
3088 FORMAT(10I3)
8890 FORMAT(5X,*CAPACITIES OF VEHICLES*,10I5)
IF(JPOLCY.GT.1)GO TO 901
DO 200 I=1,NN
DO 200 J=1,NN
MMX(I,J)=0
200 CONTINUE
DO 201 I=1,NV
MPL=N(I)
JS=I
DO 202 J=1,MPL
KRTT=KRT(I,J)
MMX(JS,KRTT)=1
JS=KRTT
202 CONTINUE
MMX(JS,I)=1
201 CONTINUE
901 IPOLCY=0
PRINT 399,JPOLCY
PRINT 8890,(C(I),I=1,NV)
900 DO 110 I=1,NN
DO 110 J=1,NN
JMX(I,J)=MMX(I,J)
110 CONTINUE
PRINT 8892
8892 FORMAT(5X,33(*-*))
IPOLCY=IPOLCY+1
IF(IPOLCY.GT.3)GO TO 7000
C*****POLICY FOR CONSIDERING OVERLOADED ROUTES IN RANDOM ORDER
PRINT 851,IPOLCY
851 FORMAT(5X,*ROUTE-POLICY*,I3)
MOTI=0
CALL GUDIYA(JMX,KRT,N)
1161 KEJ=0
JEJ=0
1001 CALL CAPCON(KRT,N,OVC,UVC)
IF(IPOLCY.EQ.1)GO TO 1002
GO TO 1100

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```

IF(OVC(I).EQ.0)GO TO 119
JEJ=JEJ+1
KAPC(JEJ)=I
CALL SEARCH(N,OVC,UVC,KAPC,JEJ,KEP,KEJ)
CALL CAPCON(KRT,N,OVC,UVC)
IF(IPCLCY.EQ.1)GO TO 1002
IF(IPCLCY.EQ.2)GO TO 1200
IF(IPCLCY.EQ.3)GO TO 1300
119  CONTINUE
6000  CONTINUE
      CALL DISCAL(TD)
811  FORMAT(/5X,*TOTAL DISTANCE =*,I5)
      IF(KEJ.EQ.0)GO TO 800
      DO 960 I=1,KEJ
      KAMO=KEP(I)
      DO 961 II=1,NV
      IF(UVC(II).EQ.0)GO TO 982
      IMEK(II)=D(KAMO)-UVC(II)
      GO TO 961
982  IMEK(II)=5000
961  CONTINUE
      CALL MIN(IMEK,NV,NVH,IMK)
      IF(IMK.EQ.5000)GO TO 979
      KRZP=KRT(NVH,1)
      JMX(NVH,KAMO)=1
      JMX(NVH,KRZP)=0
      JMX(KAMO,KRZP)=1
      CALL GUDIYA(JMX,KRT,N)
      CALL CAPCON(KRT,N,OVC,UVC)
960  CONTINUE
      MOTI=MOTI+1
      IF(MOTI.EQ.21)GO TO 979
      GO TO 1161
979  PRINT 973
973  FORMAT(/10X,*OMMITED CUSTOMER REMAINS*)
      GO TO 900
800  CONTINUE
850  FORMAT(/10X,*THERE IS NO CUSTOMERS LEFT UNASSIGNED*)
      CALL REFINE(N)
      PRINT 1350
1350  FORMAT(10X,*FINAL ROUTES OBTAINED ARE*)
      PRINT 1360
      PRINT 4618
      NVN=NV-1
      DO 1351 I=1,NV
      NEP=N(I)
      DO 1352 J=1,NEP
      KRIM=KRT(I,J)
      KRT(I,J)=KRIM-NVN
1352  CONTINUE
1351  CONTINUE
      DO 3040 I=1,NV
      LIZI=N(I)
      NST=0
      NID=0
      JRTK=0
      JSS=1
      DO 3041 J=1,LIZI
      KLIZ=KRT(I,J)

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PRO01398
PRO01399
PRO01400
PRO01401
PRO01402

```


KAPO(JEJ)=NVE

GO TO 5000

7000 GO TO 8888

7010 STOP

END

ISN

SOURCE STATEMENT

```

0 $IBFTC SEARCH
1   SJBROUTINE SEARCH(N,OVC,UVC,KAPO,JEJ,KEP,KEJ)
2   INTEGER B,D,OVC,UVC,C,T,BB,A,OBJFN
3   COMMON/STS/NV,NN
4   COMMON/JLM/D,C
5   COMMON/OPM/B,T,JMX,KRT
6   DIMENSION KRT(10,30),M(10),OVC(10),UVC(10)
7   DIMENSION KAPO(10),KEP(10),JMX(40,40)
10  DIMENSION B(40,40),D(40),JEST(40),MINT(40),ISC(40),ICS(40)
11  DIMENSION MINMUM(40),IV1(40),IV2(40),MINDIS(40),IW1(40),IW2(40)
12  DIMENSION ITEEN(10,30),IB(10),A(10,40),BB(10),OBJFN(40),NX(40)
13  DIMENSION NDIS(40),NXX(40),C(10)
14  MGM=KAPO(JEJ)
15  NVS=N(MGM)
16  DO 2 J=1,NVS
17  K_=0
20  KY=KRT(MGM,J)
21  DO 3 JJ=1,NN
22  DO 1 JP=1,JEJ
23  MGS=KAPO(JP)
24  IF(D(KY).LE.UVC(MGS))GO TO 1
27  IF(JJ.EQ.MGS)GO TO 3
32  NVF=N(MGS)
33  DO 101 JPS=1,NVF
34  KZY=KRT(MGS,JPS)
35  IF(JJ.EQ.KZY)GO TO 3
40  101 CONTINUE
42  1 CONTINUE
44  IF(KEJ.EQ.0)GO TO 1520
47  DO 1510 JAJC=1,KEJ
50  MGZK=KEP(JAJC)
51  IF(JJ.EQ.MGZK)GO TO 3
54  1510 CONTINUE
56  1520 IDIS=3(JJ,KY)
57  KQ=0
60  DO 5 JK=1,NN
61  IF(JMX(JJ,JK).EQ.0)GO TO 5
64  JDIS=B(KY,JK)
65  MDIS=IDIS+JDIS
66  KDIS=B(JJ,JK)
67  KQ=KQ+1
70  NDIS(KQ)=MDIS-KDIS
71  JEST(KQ)=JK
72  5 CONTINUE
74  CALL MIN(NDIS,KQ,LSD,IMINA)
75  KL=KL+1
76  MINT(KL)=IMINA
77  ISC(KL)=JJ
100  ICS(KL)=JEST(LSD)
101  3 CONTINUE
103  IF(KL.EQ.0)GO TO 999
106  995 CALL MIN(MINT,KL,LST,IMIN)
107  IF(IMIN.EQ.9999)GO TO 999
112  MINMUM(J)=IMIN
113  IV1(J)=ISC(LST)

```

ISN	SOURCE STATEMENT
114	IV2(J)=ICS(LST)
115	IF(J.EQ.1)GO TO 998
120	JTA=J-1
121	DO 1082 JQA=1,JTA
122	IF(IV1(J).EQ.IV1(JQA))GO TO 997
125	1082 CONTINUE
127	GO TO 998
130	997 MINT(LST)=9999
131	GO TO 996
132	998 KEKE=0
133	IF(JMX(MGM,KY).EQ.0)GO TO 9
136	LKY=MGM
137	KEKE=KEKE+B(LKY,KY)
140	GO TO 8
141	9 DO 6 JJ=1,NVS
142	LKY=KRT(MGM,JJ)
143	IF(JMX(LKY,KY).EQ.0)GO TO 6
146	KEKE=KEKE+B(LKY,KY)
147	GO TO 8
150	5 CONTINUE
152	8 IF(JMX(KY,MGM).EQ.0)GO TO 10
155	MKY=MGM
156	KEKE=KEKE+B(KY,MKY)
157	GO TO 11
160	10 DO 12 JJ=1,NVS
161	MKY=KRT(MGM,JJ)
162	IF(JMX(KY,MKY).EQ.0)GO TO 12
165	KEKE=KEKE+B(KY,MKY)
166	GO TO 11
167	12 CONTINUE
171	11 KAKU=KEKE-B(LKY,MKY)
172	MINDIS(J)=IMIN-KAKU
173	IW1(J)=LKY
174	IW2(J)=MKY
175	GO TO 2
176	999 IMIN=9999
177	IV1(J)=0
200	IV2(J)=0
201	GO TO 998
202	2 CONTINUE
204	KINN=1
205	IF(JEJ.EQ.1)GO TO 20
210	JET=JEJ-1
211	DO 400 I=1,JET
212	KIN=0
213	MGST=KAPD(1)
214	NVFS=N(MGST)
215	DO 500 J=1,NVS
216	KZW=KRT(MGM,J)
217	DO 600 JJ=1,NVFS
220	IF(IV1(J).EQ.KRT(MGST,JJ))GO TO 700
223	500 CONTINUE
225	DO 750 JJ=1,NVFS
226	IF(IV2(J).EQ.KRT(MGST,JJ))GO TO 700
231	750 CONTINUE

ISN	SOURCE STATEMENT
233	GO TO 450
234	700 KIN=KIN+1
235	ITEEN(KINN,J)=D(KZW)
236	450 ITEEN(KINN,J)=0
237	500 CONTINUE
241	IF(KIN.EQ.0)GO TO 400
244	IB(KINN)=UVC(MGST)
245	KINN=KINN+1
246	400 CONTINUE
250	20 NCONS=KINN
251	NVAR=NVS
252	DJ 2203 J=1,NVS
253	KRTT=KRT(MGM,J)
254	A(1,J)=D(KRTT)
255	2203 CONTINUE
257	B3(1)=OVC(MGM)
260	IF(NCONS.EQ.1)GO TO 2500
263	DJ 2204 I=2,NCONS
264	JIN=I-1
265	DJ 2206 J=1,NVAR
266	B3(I)=IB(JIN)
267	A(I,J)=ITEEN(JIN,J)
270	2206 CONTINUE
272	2204 CONTINUE
274	2500 DJ 2202 J=1,NVAR
275	OBJFN(J)=MINDIS(J)
276	2202 CONTINUE
300	DJ 840 I=1,NVS
301	840 NX(I)=0
303	CALL ZERO1(NVAR,NCONS,A,BB,OBJFN,NXX,IAB)
304	DJ 825 I=1,IAB
305	NXT=NXX(I)
306	NX(NXT)=1
307	825 CONTINUE
311	DJ 6000 J=1,NVS
312	KRTA=KRT(MGM,J)
313	IF(NX(J).EQ.1)GO TO 6001
316	GO TO 6000
317	5001 IF(MINDIS(J).GT.9000)GO TO 6002
322	IVV1=IV1(J)
323	IVV2=IV2(J)
324	JMX(IVV1,IVV2)=0
325	JMX(IVV1,KRTA)=1
326	JMX(KRTA,IVV2)=1
327	GO TO 6003
330	5002 KEJ=KEJ+1
331	KEP(KEJ)=KRTA
332	IVV1=0
333	IVV2=0
334	6003 IWW1=IW1(J)
335	IWW2=IW2(J)
336	IF(JMX(IWW1,KRTA).EQ.1)GO TO 6050
341	IF(JMX(MGM,KRTA).EQ.1)GO TO 6069
344	DJ 6060 JJ=1,NVS
345	KRAC=KRT(MGM,JJ)

MEG250

FORTRAN SOURCE LIST SEARCH

ISN

SOURCE STATEMENT

```
346      IF(JMX(KRAC,KRTA).EQ.1)GO TO 6070
351 6060 CONTINUE
353 6069 KRAC=MGM
354 6070 IWW1=<RAC
355 6060 JMX(IWW1,KRTA)=0
356      JMX(KRTA,IWW2)=0
357      JMX(IWW1,IWW2)=1
360 6000 CONTINUE
362      CALL GUDIYA(JMX,KRT,N)
363      RETURN
364      END
```

MEG250

IBMAP ASSEMBLY SEARCH

NO MESSAGES FOR ABOVE ASSEMBLY

ISN

SOURCE STATEMENT

```
0 $IBFTC CAPCON
1  SUBROUTINE CAPCON(KRT,N,DVC,UVC)
2  COMMON/STS/NV,NN
3  COMMON/JLM/D,C
4  INTEGER D,DVC,UVC,C,SUM
5  DIMENSION KRT(10,30),D(40),SUM(10),DVC(10),UVC(10),N(10),C(10)
6  DO 1 I=1,NV
7  DVC(I)=0
10  UVC(I)=0
11  SJM(I)=0
12  NVS=N(I)
13  DO 2 J=1,NVS
14  KRTT=KRT(I,J)
15  SJM(I)=SUM(I)+D(KRTT)
16  2  CONTINUE
20  IF(SUM(I).LE.C(I))GO TO 3
23  DVC(I)=SUM(I)-C(I)
24  GO TO 1
25  3  UVC(I)=C(I)-SUM(I)
26  1  CONTINUE
30  RETURN
31  END
```

MEG250

IBMAP ASSEMBLY CAPCON

NO MESSAGES FOR ABOVE ASSEMBLY

MEG250

FORTRAN SOURCE LIST

ISN

SOURCE STATEMENT

```
0 $IBFTC MIN
1 SUBROUTINE MIN(P,N,K,RMIN)
2 INTEGER P,RMIN,SUM
3 DIMENSION P(100)
4 K=1
5 SJM=P(1)
6 IF(N.EQ.1)GO TO 2
11 DO 1 I=2,N
12 IF(P(I).GE.SUM)GO TO 1
15 K=I
16 SJM=P(I)
17 1 CONTINUE
21 2 RMIN=SUM
22 RETURN
23 END
```

MEG250

IBMAP ASSEMBLY MIN

NO MESSAGES FOR ABOVE ASSEMBLY

ISN

SOURCE STATEMENT

```
0 $IBFTC GUDIYA
1     SJBROUTINE GUDIYA(JMX,KRT,N)
2     COMMON/STS/NV,NN
3     DIMENSION JMX(40,40),KRT(10,30),N(10)
4     DO 1 I=1,NV
5     K=0
6     DO 2 J=1,NN
7     IF(JMX(I,J).EQ.1)GO TO 3
12    2 CONTINUE
14    3 J2=J
15    5 J1=J2
16    K=K+1
17    KRT(I,K)=J1
20    DO 130 JJ=1,NN
21    IF(JMX(J1,JJ).EQ.1)GO TO 4
24    130 CONTINUE
26    4 J2=JJ
27    IF(J2.EQ.1)GO TO 6
32    GO TO 5
33    5 N(I)=K
34    1 CONTINUE
36    RETURN
37    END
```

MEG250

IBMAP ASSEMBLY GUDIYA

NO MESSAGES FOR ABOVE ASSEMBLY

ISN

SOURCE STATEMENT

```

0 $IBFTC ZERO1
1      SJBROUTINE ZERO1(NN,MM,A,B,C,JOPT,IAB)
~ 2      INTEGER BMOST
3      INTEGER Y,A,B,C,V, SORT
4      INTEGER TEMP,ZMIN,CJSUM,ZOPT,SUMCR,APDS,YASUM,CFSUM
5      DIMENSION JS(40),Y(10),JSUL(40),NS(40),ME(40),V(40),MF(40)
6      DIMENSION JP(40),JR(10,40),NR(10),SORT(40),JOPT(40)
7      DIMENSION INEQ(10),A(10,40),B(10),C(40),INVC(40)
10     MSMAX=100
11     MNMX=0
12     INEQ(1)=1
13     IF (MM.EQ.1) GO TO 5010
16     DO 5000 I=2,MM
17     INEQ(I)=2
20     5000 CONTINUE
22     5010 DO 43 I=1,40
23     JP(I)=0
24     JS(I)=0
25     JSUL(I)=0
26     SORT(I)=0.0
27     DO 42 J=1,10
30     42 JR(J,I)=0
32     43 INVC(I)=0
    C*** READ PROBLEM, WRITE INITIAL TABLEAU
34     CALL GERD(NN,MM,MNMX,INEQ,A,B,C,INVC,MSMAX)
35     DO 49 I=1,MM
36     NR(I) = 0
37     DO 45 J=1,NN
40     IF (A(I,J)) 45, 44, 44
41     44 NR(I) = NR(I) +1
42     IABC = NR(I)
43     IF (A(I,J)) 4400,4400,4401
44     4400 SORT(IABC) = 7777777
45     GO TO 4402
46     4401 SORT(IABC) =C(J)/A(I,J)
47     4402 JR(I,IABC)=J
50     45 CONTINUE
52     IF (NR(I)-1) 49, 49, 46
53     46 IAB=NR(I)-1
54     DO 48 K=1,IAB
55     KP1=K+1
56     IABC=NR(I)
57     DO 48 L=KP1,IABC
60     IF (SORT(K)-SORT(L)) 48, 48, 47
61     47 TEMP=SORT(K)
62     SORT(K) = SORT(L)
63     SORT(L)=TEMP
64     ITEMP=JR(I,K)
65     JR(I,K)=JR(I,L)
66     JR(I,L)=ITEMP
67     48 CONTINUE
72     49 CONTINUE
74     ZMIN=7777777
75     MS=1
76     300 BMOST = B(MM)

```

ISN	SOURCE STATEMENT
77	IMAX=1
100	DO 304 I=1,MM
101	IF (BMOST-B(I)) 302, 304, 304
102 302	BMOST=B(I)
103	IMAX=I
104 304	CONTINUE
106 305	IABC=NR(IMAX)
107	DO 325 I=1,IABC
110	JS(I)=JR(IMAX,I)
111	DO 319 K=1,MM
112	Y(K)=-B(K)
113	DO 318 L=1,I
114	IAB=JS(L)
115 318	Y(K)=Y(K)+A(K,IAB)
117	IF (Y(K)) 325,319,319
120 319	CONTINUE
122	CJSUM=0.
123	DO 323 J=1,I
124	IAB=JS(J)
125	CJSUM=CJSUM+C(IAB)
126 323	CONTINUE
130	JRME=I
131	GO TO 72
132 325	CONTINUE
134	JRME=NR(IMAX)
135	GO TO 100
136 52	MS=MS+1
C***	ITERATION COUNTER, EXIT IF MS MAX EXCEEDED
C	
137	IF (MS-MSMAX) 54, 54, 53
140 53	CONTINUE
141	IF (JRME-39) 59, 59, 51
142 51	CONTINUE
143 59	K=1
144	DO 354 J=1,NN
145	IF (INVC(J)) 354,354,352
146 352	JP(K)=J
147	K=K+1
150 354	CONTINUE
152	IF (NN-39) 356,356,355
153 355	CONTINUE
154 356	GO TO 993
155 54	DO 57 IY=1,NN
156	I=IY
157	IF (JS(I)) 55, 58, 55
160 55	IF (NN-1) 57, 56, 57
161 56	I=I+1
162	GO TO 58
163 57	CONTINUE
165 58	JRME=I-1
166	CJSUM=0
167	DO 64 I=1,JRME
170	IF (JS(I)) 64, 64, 62
171 62	IAB=JS(I)
172	CJSUM=CJSUM+C(IAB)

ISN	SOURCE STATEMENT
173	64 CONTINUE
175	DO 70 I=1,MM
176	Y(I)=-B(I)
177	DO 68 J=1,JRML
200	IF (JS(J)) 68, 68, 67
201	67 IAB=JS(J)
202	Y(I)=Y(I)+A(1,IAB)
203	68 CONTINUE
205	70 CONTINUE
207	DO 71 I=1,MM
210	IF (Y(I)) 100, 71,71
211	71 CONTINUE
213	IF (ZMIN-CJSUM) 73, 73, 72
214	72 ZMIN= CJSUM
215	73 CONTINUE
216	83 DO 76 J=1,JRME
217	75 JOPT(J)=JS(J)
221	IAB=JRME+1
222	DO 79 J=IAB,NN
223	79 JOPT(J)=0
225	74 IF (JSUL(JRME)) 75, 92, 92
226	75 DO 80 I=1,JRME
227	J=JRME+1-I
230	IF (JSUL(J)) 80, 85, 85
231	80 CONTINUE
	C*** PROBLEM COMPLETE, WRITE OUTPUT
	C
233	K=1
234	DO 84 J=1,NN
235	IF (INVC(J)) 84, 84, 82
236	82 JP(K)=J
237	K=K+1
240	84 CONTINUE
242	88 CONTINUE
243	DO 400 K=1,NN
244	400 JP(K)=0
246	DO 405 J=1,NN
247	IF (JOPT(J)) 401,405,402
250	401 IAB=-JOPT(J)
251	JP(IAB)=JOPT(J)
252	GO TO 405
253	402 IAB=JOPT(J)
254	JP(IAB)=JOPT(J)
255	405 CONTINUE
257	K=1
260	DO 412 J=1,NN
261	IF (JP(J)) 406,406,407
262	406 IF (INVC(J)) 412,412,409
263	407 IF (INVC(J)) 409,409,412
264	409 JOPT(K)=J
265	K=K+1
266	412 CONTINUE
270	IF (K-1-39) 413,413,414
271	413 IAD=K-1
272	GO TO 415

ISN	SOURCE STATEMENT
273	414 CONTINUE
274	IAB=K-1
275	415 ZOPT=0
276	IAB=K-1
277	DJ 418 J=1,IAB
300	IABC = IABS(ZOPT(J))
301	IF (INVC(IABC)) 417,417,416
302	416 ZOPT = ZOPT - C(IABC)
303	GJ TO 418
304	417 ZOPT = ZOPT + C(IABC)
305	418 CONTINUE
307	IF (MNMX) 420,420,419
310	419 ZOPT=-ZOPT
311	420 CONTINUE
312	GJ TO 993
313	85 JSUL(J)=-1
314	JS(J)=-JS(J)
315	IBC=J+1
316	DJ 90 K=IBC,JRME
317	JS(K)=0
320	90 JSUL(K)=0
322	GJ TO 52
323	92 JS(JRME)=-JS(JRME)
324	JSUL(JRME)=-1
325	GJ TO 52
326	100 DJ 102 J=1,NN
327	102 NS(J)=1
331	DJ 106 J=1,JRME
332	IF (JS(J)) 103,106,104
333	103 JNEG=-JS(J)
334	NS(JNEG)=0
335	GJ TO 106
336	104 IABC=JS(J)
337	NS(IABC)=0
340	106 CONTINUE
342	DJ 120 I=1,NN
343	IF (NS(I)) 120,120,108
344	108 IF (C(I)-ZMIN+CJSUM) 120,110,110
345	110 NS(I)=0
346	120 CONTINUE
350	121 DJ 122 I=1,NN
351	122 ME(I)=1
353	DJ 140 I=1,MM
354	IF (Y(I)) 132,140,140
355	132 DJ 135 J=1,NN
356	IF (A(I,J)) 135,135,134
357	134 ME(J)=0
360	135 CONTINUE
362	140 CONTINUE
364	DJ 150 J=1,NN
365	IF (NS(J)) 150,150,144
366	144 IF (ME(J)) 150,150,146
367	146 NS(J)=0
370	150 CONTINUE
372	DJ 160 J=1,NN

ISN	SOURCE STATEMENT
373	IF (NS(J)) 160,160,167
374 160	CONTINUE
376	GO TO 74
377 167	MARKF=0
400	DO 183 I=1,MM
401	IF (Y(I)) 169,183,183
402 169	SJMCR=0
403	APOS=0
404	IABC=NR(I)
405	DO 180 N=1,IABC
406	IAB=JR(I,N)
407	IF (NS(IAB)) 130,180,171
410 171	IAB=JR(I,N)
411	SJMCR=SUMCR+C(IAB)
412	APOS=APOS+A(I,IAB)
413	IF (SUMCR-ZMIN+CJSUM) 176,177,177
414 176	IF (APOS+Y(I)) 180,181,183
415 177	IF (APOS+Y(I)) 74, 74,183
416 180	CONTINUE
420	GO TO 74
421 181	IF (N-NR(I)) 173,182,182
422 173	IABC=NR(I)
423	DO 174 K=N,IABC
424	IAB=JR(I,K)
425	IF (NS(IAB)) 174,174,183
426 174	CONTINUE
430 182	MARKF=1
431 183	CONTINUE
433	IF (MARKF) 190,190,240
434 190	DO 210 J=1,NN
435	IF (NS(J)) 210,210,192
436 192	YASUM=0
437	DO 198 I=1,MM
440	IF (Y(I)+A(I,J)) 193,193,198
441 193	YASUM=YASUM+Y(I)+A(I,J)
442 198	CONTINUE
444	V(J)=YASUM
445 210	CONTINUE
447	DO 230 IY=1,NN
450	J=IY
451	IF (NS(J)) 230,230,218
452 218	IF (NN-J) 235,235,219
453 219	L=J+1
454	DO 226 K=L,NN
455	IF (NS(K)) 226,226,220
456 220	IF (V(J)-V(K)) 230,226,226
457 226	CONTINUE
461	DO 229 I=L,NN
462	IF (NS(I)) 229,229,225
463 225	IF (V(J)-V(I)) 227,227,229
464 227	IF (C(J)-C(I)) 229,229,228
465 228	J=I
466 229	CONTINUE
470	GO TO 235
471 230	CONTINUE

ISN

SOURCE STATEMENT

```
473 235 JS(JRME+1)=J
474      GO TO 52
475 240 DO 241 J=1,NN
476 241 MF(J)=0
500      DO 255 I=1,MM
501      IF (Y(I)) 243,256,256
502 243 APOS=0
503      DO 248 J=1,NN
504      IF (NS(J)) 248,248,248
505 245 IF (A(I,J)) 248,248,246
506 245 APOS=APOS+A(I,J)
507 248 CONTINUE
511      IF (APOS + Y(I)) 256, 249,256
512 249 DO 255 K=1,NN
513      IF (NS(K)) 255,255,250
514 250 IF (A(I,K)) 255,255,251
515 251 MF(K)=1
516 255 CONTINUE
520 255 CONTINUE
522      CFSUM=0
523      DO 262 I=1,NN
524      IF (MF(I)) 262,262,260
525 260 CFSUM=CFSUM+C(I)
526 262 CONTINUE
530      IF (CJSUM+CFSUM-ZMIN) 263,74, 74
531 263 IF (MS-1) 264,264,265
532 264 J=1
533      GO TO 267
534 265 J=JRME+1
535 267 DO 268 I=1,NN
536      IF (MF(I)) 268,268,266
537 266 JS(J)=I
540      J=J+1
541 268 CONTINUE
543      GO TO 52
544 993 RETURN
545      END
```

MEG250

IBMAP ASSEMBLY ZERO1

NO MESSAGES FOR ABOVE ASSEMBLY

ISN

SOURCE STATEMENT

```

0 $IBFTC GERD
1      SJBROUTINE GERD(NN,MM,MNMX,INEQ,A,B,C,INVC,MSMAX)
2      DIMENSION INEQ(10),A(10,40),B(10),C(40),INVC(40)
3      INTEGER A,B,C,SUMA
4      MMM=MM
5      IF (MNMX) 2,4,2
6      2   DO 3 J=1,NN
7      3   C(J)=-C(J)
11     4   DO 25 J=1,MM
12     5   IF (INEQ(J)-1) 25,25,5
13     6   IF (INEQ(J)-2) 25,8,6
14     7   IF (INEQ(J)-3) 25,15,15
15     8   DO 10 K=1,NN
16    10   A(J,K)=-A(J,K)
20     B(J)=-B(J)
21     GO TO 25
22    15   MMM=MM+1
23     DO 20 K=1,NN
24    20   A(MMM,K)=-A(J,K)
26     B(MMM)=-B(J)
27    25   CONTINUE
31     MM=MMM
32     DO 30 J=1,NN
33     IF (C(J)) 27,30,30
34    27   C(J)=-C(J)
35     INVC(J)=1
36     DO 28 I=1,MM
37    28   A(I,J)=-A(I,J)
41    30   CONTINUE
43     DO 35 I=1,MM
44     SJMA=0
45     DO 34 J=1,NN
46     IF (INVC(J)) 34,34,32
47    32   SUMA=SUMA+A(I,J)
50    34   CONTINUE
52     B(I)=B(I)+SUMA
53    35   CONTINUE
55     RETURN
56     END

```

MEG250

IBMAP ASSEMBLY GERD

NO MESSAGES FOR ABOVE ASSEMBLY

MEG250

FORTRAN SOURCE LIST

ISN

SOURCE STATEMENT

```
0 $IBFTC DISCAL
1   SJBROUTINE DISCAL(TD)
2   COMMON/STS/NV,NN
3   COMMON/DPM/B,T,JMX,KRT
4   INTEGER TD,B,T
5   DIMENSION JMX(40,40),B(40,40),KRT(10,30)
6   TD=0
7   DO 1 I=1,NN
10  DO 2 J=1,NN
11      IF(JMX(I,J).EQ.1)GO TO 3
14      2 CONTINUE
16      3 J1=J
17      TD=TD+B(I,J1)
20      1 CONTINUE
22      RETURN
23      END
```

MEG250

IBMAP ASSEMBLY DISCAL

NO MESSAGES FOR ABOVE ASSEMBLY

ISN

SOURCE STATEMENT

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0 $IBFTC REFIN
1 SUBROUTINE REFIN(N)
C*****PROGRAM FOR 10 VEHICLES AND 30 CUSTOMERS
2 DIMENSION N(10),D(40),B(40,40),KRT(10,30),MMX(40,40),JMX(40,40)
3 DIMENSION NDIS(40),L1(40),L2(40),L(40),L3(40),OVC(10),UVC(10)
4 DIMENSION MCUS(30),MNUS(30),MROUT(30,10),NW1(30),NW2(30),NKDIS(30)
5 DIMENSION L4(40)
6 DIMENSION NS1(30),NS2(40),NSS1(30),NSS2(30),NZDIS(30)
7 DIMENSION C(10)
10 DIMENSION NZOT(40)
11 INTEGER C
12 INTEGER TD,D,B,OVC,UVC,T
13 COMMON/DPM/B,T,JMX,KRT
14 COMMON/STS/NV,NN
15 COMMON/JLM/D,C
16 CALL DISCAL(TD)
17 ITD=TD
20 DO 10 I=1,NN
21 DO 10 J=1,NN
22 MMX(I,J)=JMX(I,J)
23 10 CONTINUE
26 DO 100 I=1,NV
27 KSP=N(I)
30 KSPP=KSP
31 IF(KSP.EQ.1)GO TO 100
34 DO 101 J=1,KSP
35 IF(N(I).EQ.1)GO TO 100
40 IF(KSPP.LT.J)GO TO 100
43 KT=KRT(I,J)
44 KQ=0
45 DO 102 JJ=1,NN
46 DO 103 KK=1,KSPP
47 KTT=KRT(I,KK)
50 IF(JJ.EQ.1)GO TO 102
53 IF(JJ.EQ.KTT)GO TO 102
56 103 CONTINUE
60 IDIS=B(JJ,KT)
61 DO 104 JK=1,NN
62 IF(JMX(JJ,JK).EQ.1)GO TO 105
65 104 CONTINUE
67 105 JDIS=B(KT,JK)
70 KDIS=B(JJ,JK)
71 KQ=KQ+1
72 NDIS(KQ)=IDIS+JDIS-KDIS
73 L1(KQ)=JJ
74 L2(KQ)=JK
75 L(KQ)=KT
76 DO 106 JJK=1,NN
77 IF(JMX(JJK,KT).EQ.1)GO TO 107
102 IF(JMX(KT,JJK).EQ.1)GO TO 108
105 GO TO 106
106 107 L3(KQ)=JJK
107 GO TO 106
110 108 L4(KQ)=JJK
111 106 CONTINUE

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ISN	SOURCE STATEMENT
113	102 CONTINUE
115	CALL MIN(NDIS,KQ,KQQ,IMIN)
116	NP5=L(KQQ)
117	NP1=L1(KQQ)
120	NP2=L2(KQQ)
121	NP3=L3(KQQ)
122	NP4=L4(KQQ)
123	JMX(NP3,NP5)=0
124	JMX(NP5,NP4)=0
125	JMX(NP3,NP4)=1
126	JMX(NP1,NP5)=1
127	JMX(NP5,NP2)=1
130	JMX(NP1,NP2)=0
131	CALL GUDIYA(JMX,KRT,N)
132	DO 109 II=1,NV
133	NKST=N(II)
134	DO 110 IK=1,NKST
135	KMT=KRT(II,IK)
136	IF(L1(KQQ).EQ.KMT)GO TO 111
141	IF(L2(KQQ).EQ.KMT)GO TO 111
144	110 CONTINUE
146	109 CONTINUE
150	111 NRT=II
C*****NP5 IS THE CUSTOMER ON ROUTE I WHICH IS TO BE SHIFTED TO SOME OTHER	
C*****NP1 AND NP2 ARE NEW CONNECTIONS	
C*****NRT IS THE ROUTE TO WHICH CUSTOMER L(KQQ) IS SHIFTED	
151	KTZ=N(II)
152	CALL CAPCON(KRT,N,OVC,UVC)
153	7539 FFORMAT(//5X,*SUBTOUT NO.*,5X,*OVC(.)*5X,*UVC(.)*5X,*PATH SEQ.*//)
154	7339 FFORMAT(10X,I2,8X,I5,6X,I3,8X,30I3)
155	IF(OVC(II).EQ.0)GO TO 4889
160	K3=0
161	DO 112 IR=1,KTZ
162	KCT=KRT(II,IR)
163	IF(D(KCT).GT.OVC(II))GO TO 113
166	GO TO 112
167	113 K3=K3+1
170	MCUS(K3)=KCT
171	112 CONTINUE
C FOR ACCOMODATING NPS IN IT) MCUS(.) IS ACTUAL CUSTOMER ON ROUTE	
C*****K3 IS THE NO. OF CUSTOMERS PERMISSIBLE FOR SHIFTING FROM ROUTE	
C** NOW CHECK WHICH CUSTOMERS OUT OF ABOVE MCUS(.) CAN BE SHIFTED TO	
C OTHER ROUTES AND FOR EACH OF THESE CUSTOMERS, NOTE THE POSSIBLE	
173	KBB=0
174	IF(K3.EQ.0)GO TO 5879
177	KBR=0
200	DO 114 IU=1,K3
201	MCUST=MCUS(IU)
202	KBB=KBB+1
203	K3L=0
204	DO 115 IT=1,NV
205	IF(IT.EQ.II)GO TO 115
210	IF(UVC(IT).GE.D(MCUST))GO TO 116
213	GO TO 115
214	116 K3L=K3L+1

ISN	SOURCE STATEMENT
215	IF(KBL.GE.2)GO TO 1139
220	KBR=KBR+1
221	NZOT(KBR)=KBL
222	MVUS(KBR)=MCUST
223	1139 MROUT(KBR,KBL)=IT
224	115 CONTINUE
226	114 CONTINUE
	C***** KER IS THE NO. OF CISTOMERS ON ROUTE II WHICH CAN BE SHIFTED TO
	C OTHER ROUTES AND DELETION OF WHICH CAN ACCOMODATE NPS FROM I ON
230	IF(KBR.EQ.0)GO TO 5879
	C*** ABOVE STATEMENT MEANS NO CUSTOMER CAN BE DELETED FROM ROUTE II
	C SO CONSIDER NEXT CUSTOMER ON ROUTE I.
233	DO 117 IZ=1,KBR
234	MSC=MVUS(IZ)
235	DO 118 IWK=1,NN
236	IF(JMX(IWK,MSC).EQ.1)GO TO 119
241	GO TO 118
242	119 NW1(IZ)=IWK
243	118 CONTINUE
245	DO 1118 IWKQ=1,NN
246	IF(JMX(MSC,IWKQ).EQ.1)GO TO 120
251	GO TO 1118
252	120 NW2(IZ)=IWKQ
253	1118 CONTINUE
255	117 CONTINUE
257	DO 121 IZ=1,KBR
260	MSC=MVUS(IZ)
261	NPLM=NZOT(IZ)
262	KCONT=0
263	DO 122 IZK=1,NN
264	DO 123 IUK=1,NPLM
265	KROUT=MROUT(IZ,IUK)
266	NJW=N(KROUT)
267	DO 124 JUK=1,NUW
270	KARR=KRT(KROUT,JUK)
271	IF(IZK.EQ.KARR)GO TO 125
274	GO TO 124
275	125 MKDIS=B(KARR,MSC)
276	DO 126 IWKK=1,NN
277	IF(JMX(KARR,IWKK).EQ.1)GO TO 127
302	126 CONTINUE
304	127 JKDIS=B(MSC,IWKK)
305	KKDIS=B(KARR,IWKK)
306	KCONT=KCONT+1
307	NKDIS(KCONT)=MKDIS+JKDIS-KKDIS
310	NS1(KCONT)=KARR
311	NS2(KCONT)=IWKK
312	124 CONTINUE
314	123 CONTINUE
316	122 CONTINUE
320	CALL MIN(NKDIS,KCONT,KCENT,JIN)
321	NSS1(IZ)=NS1(KCENT)
322	NSS2(IZ)=NS2(KCENT)
323	NATO=NW1(IZ)
324	MATO=NW2(IZ)

ISN	SOURCE STATEMENT
325	MJPIS=B(NATO, MSC)
326	NJPIS=B(MSC, MATO)
327	KJPIS=B(NATO, MATO)
330	MZDIS=MJPIS+NJPIS-KJPIS
331	NZDIS(IZ)=JIN-MZDIS
332 121	CONTINUE
334	CALL MIN(NZDIS, KBR, KBRR, JINE)
335	NY=MNUS(KBRR)
336	NY1=NW1(KBRR)
337	NY2=NW2(KBRR)
340	NY3=NSS1(KBRR)
341	NY4=NSS2(KBRR)
342	JMX(NY1, NY2)=1
343	JMX(NY1, NY)=0
344	JMX(NY, NY2)=0
345	JMX(NY3, NY)=1
346	JMX(NY, NY4)=1
347	JMX(NY3, NY4)=0
350	CALL GUDIYA(JMX, KRT, N)
351	CALL CAPCON(KRT, N, OVC, UVC)
352 4889	CONTINUE
353	CALL DISCAL(TD)
354	NTD=TD
355	IF(NTD.LT.ITD)GO TO 160
360 5879	DJ 140 IES=1, NV
361	DJ 140 JES=1, NN
362	JMX(IES, JES)=MMX(IES, JES)
363 140	CONTINUE
366	GO TO 150
367 160	DJ 200 IFZ=1, NN
370	DJ 200 IEW=1, NV
371	JMX(IFZ, IEW)=JMX(IFZ, IEW)
372 200	CONTINUE
375	ITD=NTD
376 150	CALL GUDIYA(JMX, KRT, N)
377	CALL CAPCON(KRT, N, OVC, UVC)
400	KSPP=N(I)
401 101	CONTINUE
403 100	CONTINUE
405	CALL GUDIYA(JMX, KRT, N)
406	CALL CAPCON(KRT, N, OVC, UVC)
407	RETURN
410	END

MEG250

IBMAP ASSEMBLY REFINE

NO MESSAGES FOR ABOVE ASSEMBLY
MEG250

IBLDR -- JOB 000000

*** OBJECT PROGRAM IS BEING ENTERED INTO STORAGE AT 11 HRS. 27 M

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*****
*
*   SHORTEST PATH ALGORITHM
*
*****

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      DIMENSION D(30,30)
      INTEGER D
      READ 100,N
100   FORMAT(I3)
      NIN=N-1
      DO 101 I=1,NIN
        JJ=I+1
        READ 102,(D(I,II),II=JJ,N)
101   CONTINUE
102   FORMAT(20I4)
      DO 200 I=1,N
        DO 200 J=1,N
          IF(J.GT.I)GO TO 200
          IF(J.EQ.I)GO TO 201
          D(I,J)=D(J,I)
          GO TO 200
201   D(I,J)=0
200   CONTINUE
      DO 5010 ITR=1,6
        PRINT 400,(I,I=1,N)
400   FORMAT(1H1,////25X,*DISTANCE MATRIX*//11X,30I4/)
      DO 103 I=1,N
        PRINT 104,I,(D(I,J),J=1,N)
103   CONTINUE
104   FORMAT(5X,I2,5X,30I4)
      PRINT 500
500   FORMAT(/10X,*NOTE- D(I,J) MEANS SHORTEST DIRECT LINK BETWEEN
        6I AND J NODE*,/10X,*      D(I,J)=999 MEANS NO DIRECT LINK BETWEEN
        6I AND J NODE*)
5010  CONTINUE
      CALL FLOYD(D,N)
      DO 6010 JTR=1,6
        PRINT 300,(I,I=1,N)
300   FORMAT(1H1,////25X,*SHORTEST DISTANCE MATRIX*//11X,30I4/)
      DO 105 I=1,N
        PRINT 106,I,(D(I,J),J=1,N)
105   CONTINUE
106   FORMAT(5X,I2,5X,30I4)
6010  CONTINUE
      PRINT 700
700   FORMAT(1H1,//*FINISH*)
      STOP
      END
&IBFTC FLOYD
      SUBROUTINE FLOYD(D,N)
      INTEGER D,S
      DIMENSION D(30,30)
      DIMENSION IP(30,30)
      DO 15 I=1,N
        DO 15 J=1,N
          IP(I,J)=0
15    CONTINUE

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```
DO 12 K=1,N
DO 12 I=1,N
IF(D(I,K).EQ.999)GO TO 12
DO 11 J=1,N
IF(D(K,J).EQ.999)GO TO 11
S=D(I,K)+D(K,J)
IF(S.LT.D(I,J))GO TO 50
GO TO 11
50 D(I,J)=S
IP(I,J)=K
11 CONTINUE
12 CONTINUE
RETURN
END
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*****
*
*   CLARKE AND WRIGHTS METHOD
*
*****

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C***** THIS PROGRAM IS FOR 34 CUSTOMERS AND 1 DEPOT
DIMENSION D(35),B(35,35),C(15),KOP(35),JMX(35,35),IB(35),JB(35)
DIMENSION DROUT(15),KB(35),KIP(35),JOD(35)
DIMENSION KRT(15,35),N(15)
INTEGER B,D,DROUT,C
COMMON/SITA/NT,NN,JMX,B
C***** NC IS NO. OF CUSTOMERS AND NT IS TOTAL NO. OF VEHICLES AVAILABLE
C WHICH MIGHT BE LESS OR MORE THAN ACTUAL VEHICLES NEEDED
READ 1,NC,NT
1 FORMAT(2I3)
IF(NC.EQ.100)GO TO 9000
NN=NC+1
C*****FOR DEPOT DEMAND IS ZERO, D(1)=0
DO 3 I=1,NC
JJ=I+1
READ 4,(B(I,II),II=JJ,NN)
3 CONTINUE
4 FORMAT(20I4)
DO 1020 I=1,NN
DO 1020 J=1,NN
IF(J.GT.I)GO TO 1020
IF(J.EQ.I)GO TO 1021
B(I,J)=B(J,I)
GO TO 1020
1021 B(I,J)=999
1020 CONTINUE
IPOL=0
8049 IPOL=IPOL+1
IF(IPOL.GT.4)GO TO 9000
PRINT 250
250 FORMAT(1H1,/10X,*ROUTES OBTAINED BY CLARKE AND WRIGHT METHOD*)
READ 2,(D(J),J=1,NN)
2 FORMAT(20I4)
JPOLCY=0
8 JPOLCY=JPOLCY+1
PRINT 5050
5050 FORMAT(5X,33(*-*))
IF(JPOLCY.GT.3)GO TO 8049
1060 READ 1001,(C(I),I=1,NT)
1001 FORMAT(10I6)
PRINT 1550,JPOLCY
1550 FORMAT(/10X,*CONSIDERING VEHICLE-POLICY*,I3)
PRINT 2005,(C(I),I=1,NT)
2005 FORMAT(10X,*CAPACITIES*,10I5/)
K=0
KROUT=0
DO 101 JJK=1,NN
101 KOP(JJK)=0
DO 9 I=1,NN
DO 9 J=1,NN
JMX(I,J)=0
9 CONTINUE

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700  TR(1)=9999
    DO 10 I=2,NN
    DO 102 JJK=1,NN
    IF(KOP(JJK).EQ.I)GO TO 103
102  CONTINUE
    GO TO 104
103  IB(I)=9999
    GO TO 10
104  IB(I)=B(1,I)
    10  CONTINUE
    CALL MIN(IB,NN,NK,IBB)
    IF(IBB.EQ.9999)GO TO 4000
C*****  NK IS THE NEAREST CUSTOMER TO DEPOT AMONG UNASSIGNED CUSTOMERS
    KROUT=KROUT+1
    IF(KROUT.GT.NT)GO TO 4050
    JMX(1,NK)=1
    DROUT(KROUT)=D(NK)
500  K=K+1
    KOP(K)=NK
C*****  JB(I) IS SAVINGS OBTAINED BY CONNECTING NK TO I
    JB(1)=-9999
    JIBB=B(1,NK)
    DO 11 I=2,NN
    DO 12 KK=1,K
    IF(I.EQ.KOP(KK))GO TO 13
12  CONTINUE
    JB(I)=JIBB+B(1,I)-B(NK,I)
    GO TO 11
13  JB(I)=-9999
11  CONTINUE
    DO 107 I=1,NN
107  KB(I)=-JB(I)
    MKP=0
16  CALL MIN(KB,NN,NKK,KBB)
    IF(KBB.EQ.9999)GO TO 23
    IF(KBB.EQ.999)GO TO 15
    MKP=MKP+1
    KIP(MKP)=NKK
    KB(NKK)=999
    GO TO 16
15  CONTINUE
    DO 17 I=1,MKP
    NKT=KIP(I)
    JOD(I)=JB(NKT)
17  CONTINUE
    DO 20 I=1,MKP
    NKT=KIP(I)
    DROUT(KROUT)=DROUT(KROUT)+D(NKT)
    IF(DROUT(KROUT).GT.C(KROUT))GO TO 21
    GO TO 22
21  DROUT(KROUT)=DROUT(KROUT)-D(NKT)
20  CONTINUE
    GO TO 23
22  JMX(NK,NKT)=1
    NK=NKT
    GO TO 500
23  JMX(NK,1)=1
    GO TO 700
4000 CONTINUE

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0  TR(1)=9999
DO 10 I=2,NN
DO 102 JJK=1,NN
IF(KOP(JJK).EQ.I)GO TO 103
2  CONTINUE
GO TO 104
3  IB(I)=9999
GO TO 10
4  IB(I)=B(1,I)
0  CONTINUE
CALL MIN(IB,NN,NK,IBB)
IF(IBB.EQ.9999)GO TO 4000
***  NK IS THE NEAREST CUSTOMER TO DEPOT AMONG UNASSIGNED CUSTOMERS
KROUT=KROUT+1
IF(KROUT.GT.NT)GO TO 4050
JMX(1,NK)=1
DROUT(KROUT)=D(NK)
0  K=K+1
KOP(K)=NK
**  JB(I) IS SAVINGS OBTAINED BY CONNECTING NK TO I
JB(1)=-9999
JIBB=B(1,NK)
DO 11 I=2,NN
DO 12 KK=1,K
IF(I.EQ.KOP(KK))GO TO 13
2  CONTINUE
JB(I)=JIBB+B(I,1)-B(NK,I)
GO TO 11
3  JB(1)=-9999
1  CONTINUE
DO 107 I=1,NN
7  KB(I)=-JB(I)
MKP=0
6  CALL MIN(KB,NN,NKK,KBB)
IF(KBB.EQ.9999)GO TO 23
IF(KBB.EQ.999)GO TO 15
MKP=MKP+1
KIP(MKP)=NKK
KB(NKK)=999
GO TO 16
5  CONTINUE
DO 17 I=1,MKP
NKT=KIP(I)
JOD(I)=JB(NKT)
7  CONTINUE
DO 20 I=1,MKP
NKT=KIP(I)
DROUT(KROUT)=DROUT(KROUT)+D(NKT)
IF(DROUT(KROUT).GT.C(KROUT))GO TO 21
GO TO 22
1  DROUT(KROUT)=DROUT(KROUT)-D(NKT)
0  CONTINUE
GO TO 23
22  JMX(NK,NKT)=1
NK=NKT
GO TO 500
23  JMX(NK,1)=1
GO TO 700
000 CONTINUE

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8071E

```

KN=0
CALL BABBO(KRT,N,DIS,KN)
II=1
DO 410 I=1,KN
NPS=N(I)
PRINT 420,I,II,(KRT(I,J),J=1,NPS),II
20  FORMAT(10X,*SUBTOUR*,13,5X,3013)
10  CONTINUE
PRINT 260,DIS
50  FORMAT(/10X,*TOTAL DISTANCE =*,14)
PRINT 320,KN
10  FORMAT(10X,*REQD. VEHICLES =*,14)
GO TO 8
50  PRINT 290
10  FORMAT(/20X,*REQD. VEHICLES(ROUTES) ARE MORE THAN AVAILABLE VEH*)
GO TO 8
100 STOP
END
FTC BABBO
SUBROUTINE BABBO(KRT,N,DIS,KN)
COMMON/SITA/NT,NN,JMX,B
INTEGER B
DIMENSION B(35,35),JMX(35,35),N(15),KRT(15,35)
I=0
DIS=0
DO 2 J=1,NN
K=0
IF(JMX(1,J).EQ.1)GO TO 3
GO TO 2
J2=J
I=I+1
DIS=DIS+B(1,J2)
5 J1=J2
K=K+1
KRT(I,K)=J1
DO 130 JJ=1,NN
IF(JMX(J1,JJ).EQ.1)GO TO 4
0 CONTINUE
4 J2=JJ
DIS=DIS+B(J1,J2)
IF(J2.EQ.1)GO TO 6
GO TO 5
6 N(I)=K
2 CONTINUE
KN=1
RETURN
END
BFTC MIN
SUBROUTINE MIN(P,N,K,RMIN)
INTEGER P,RMIN,SUM
DIMENSION P(50)
K=1
SUM=P(1)
IF(N.EQ.1)GO TO 2
DO 1 I=2,N
IF(P(I).GE.SUM)GO TO 1
K=I
SUM=P(I)
1 CONTINUE

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A 31702

ME-1974-M-MOD-DET